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Performance in the 9D5 multi-place universal underwater egress trainer : physiological and behavioral correlates

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Monterey, California

THESIS

PERFORMANCE IN THE 9D5 MULTI-PLACE
UNIVERSAL UNDERWATER EGRESS
TRAINER: PHYSIOLOGICAL AND
BEHAVIORAL CORRELATES

by

Howard Marion Tillison

March 1981

Thesis Advisor: W. F. Moroney

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From 1969 through 1972, 78 Navy helicopters crashed at sea with a loss of 63 lives (10 due to injuries; the remaining 53 persons either drowned or were lost at sea). To reverse the trend toward fatalities following aircraft crashes at sea, the Navy has begun training all flight personnel in the 9D5 Multi-Place Universal Underwater Egress Trainer. This thesis examined the relationships between

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Performance in the 9D5 Multi-Place Universal Underwater Egress Trainer: Physiological and Behavioral Correlates

by

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ABSTRACT

From 1969 through 1972, 78 Navy helicopters crashed at sea with a loss of 63 lives (10 due to injuries; the remaining 53 persons either drowned or were lost at sea). To reverse the trend toward fatalities following aircraft crashes at sea, the Navy has begun training all flight personnel in the 9D5 Multi-place Universal Underwater Egress Trainer. This thesis examined the relationships between trainee performance (n=267) in the 9D5 device, swimming test scores and subjective anxiety scores. Mile-swim times were predictive of group (but not individual) performance in the 9D5 device with faster swimmers performing better. Poor egress performance when blindfolded was attributed to egress path difficulty and disorientation. Findings can be applied to the design of egress aids, training and motivation of subjects and the effects of anxiety upon subject performance in carrying out sequential tasks while totally immersed in water.

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LIST OF ABBREVIATIONS

AOC - Aviation Officer Candidate

ENL - Enlisted Aircrewman Candidate

HSD - Honestly Significant Difference

NAVY - Navy Officers

SCUBA - Self-Contained Underwater Breathing Apparatus

UDT - Underwater Demolition Team

USMC - Marine Corps Officers

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I. INTRODUCTION AND STATEMENT OF PROBLEM

A. BACKGROUND

From 1969 through 1972, 78 Navy helicopters crashed at sea with a loss of 63 lives. Only ten lives were lost due to injuries while the other 53 persons either drowned or were lost at sea. The survivors reported that the primary difficulties with egress were panic, disorientation, jammed hatches, entanglement, in-rushing water and darkness [United States Naval Flight Surgeon's Manual, 1978].

The Royal Navy, having suffered the same trends in fatalities following helicopter crashes, began training their personnel in a helicopter underwater-egress device in 1962. Since that time, Royal Navy drownings following helicopter ditchings have dropped to almost zero [Bullock, 1978].

In 1977, the United States Navy began training flight personnel in the 9D5 Multi-Place Universal Underwater Egress Trainer. The present study was conducted from May through October 1980,and examined the training performance of 267 flight students undergoing initial qualification in the 9D5.

It is hoped that training in the 9D5 device will transfer to the "real world" and improve the survival rate of ditching victims. Naval Safety Center records show that, in a 12-year period, 34 per cent of all helicopter passengers

involved in crashes at sea died. When some kind of underwater escape training had been received (such as the single-place "Dilbert Dunker" training), the fatality rate dropped to 8.5 per cent [Bullock, 1978].

B. STATEMENT OF THE PROBLEM

The following specific problem areas were identified before the research began. Two areas of interest are related directly to the 9D5 device while the third deals with a study which utilized trained Navy divers.

1. Anxiety in Subjects

The personnel in the Helicopter Aircrew Survivability Enhancement program at the Naval Air Development Center are specifically interested in the levels of anxiety experienced by trainees in the 9D5 device. Since panic was listed among the primary difficulties during underwater egress, it is necessary to understand the typical aircrewman's reaction to immersion in the 9D5 device, since that device presents a realistic simulation of the difficulties that will be encountered in a real ditching situation.

2. Performance and Training

Both Naval Air Development Center and Naval Aviation Schools Command personnel are interested in the effectiveness of the 9D5 training and the difficulties experienced by the subjects during the course of training.

It is expected that the 9D5 training will signifi-

cantly improve the proficiency of students in egress from a multi-place vehicle. This is important relative to cost-effectiveness and training effectiveness.

The difficulties experienced by the subjects undergoing training in controlled, almost ideal conditions must surely be related to difficulties encountered during an emergency ditching at sea. However, a task that is merely difficult in the 9D5 trainer would be potentially fatal in a real crash.

3. Results of a Related Study

A related experimental study in underwater egress from an actual helicopter fuselage was conducted using qualified Navy divers as subjects. For legal and ethical reasons, this is not surprising. However, the performance of subjects who are previously untrained in undersea operations must be addressed in order to judge the effectiveness of the 9D5 training and to draw conclusions which might be generalized to the broader population of Naval Aircrew personnel. Furthermore, we must be concerned with the potential helicopter passenger who is neither trained in the 9D5 device nor familiar with the aircraft in which he is riding. For these reasons, the 9D5 training session is an ideal scenario for gathering experimental data on subjects who are not contaminated by previous experience.

C. OTHER AREAS TO BE ADDRESSED

The subjects undergoing training in the 9D5 device all completed a number of physical fitness and swimming (including water survival) tests as prerequisites to the 9D5 session. It was felt that the results of some of those tests might be predictive of performance in the 9D5 device, so this issue was examined during the present study.

The importance of prediction based upon easily observable fitness-oriented measures must not be discounted. Since many more military personnel than those specifically undergoing flight training are required to submit to tests of physical fitness, it might someday be possible to predict survival rates (in a ditching situation) for non-aviation personnel (Marine Corps infantrymen, for example) in order to determine whether or not specific egress training would be valuable. Alternately, poor physical fitness could be used to screen out those non-aviation personnel who would be most likely to encounter difficulty in a ditching so that they could be restricted from over-water flights.

II. REVIEW OF LITERATURE, STRATEGY AND HYPOTHESES

The literature was examined for previous research in the areas of stress measurement, underwater performance and prediction of success in stressful situations. It must be noted that very few references dealing specifically with apneic (breath-holding) divers could be located. Literature on submarine egress training was available in abundance, but its usefulness in the present study was limited by the inherent differences between submarine escape and aircraft underwater egress, i.e. that submarine escape allows for much more time in planning and preparation. Furthermore, literature examining diver performance and anxiety dealt almost exclusively with divers in an air-breathing (SCUBA or "hard-hat") scenario, so that most problems experienced by divers in the areas of stress and performance could not be related to ditching victims. For these reasons, the scope of the literature search was severely restricted.

A. PREVIOUS STUDY OF EGRESS FROM A SUNKEN HELICOPTER

A study of escape hatch illumination as an egress aid was performed by Ryack, Smith, Champlin and Noddin [1979] of the Naval Submarine Research Laboratory using 24 Underwater Demolition Team members as experimental subjects. The subjects were exposed, over a three-day period to

immersion in an old H-3 helicopter hulk during both daylight and night conditions. An electroluminescent panel adjacent to open windows in the hulk was, on a random basis, illuminated during both daylight and night "dunkings" of the hulk. It was found that significant differences in performance occurred depending upon which seat the subject was sitting in during the simulation and depending upon illumination of the panel. No differences were found between day and night egresses. It is important to note (for later comparison) that the egress hatch for each subject was either directly behind the subject's back or directly in front of the subject across the fuselage (approximately six and one-half feet away) so that no lengthy paths requiring changes in direction were involved. The metric used in this study was the elapsed time from releasing the seat belt until passing through the prescribed window exit.

It was noted in the report that 16 instances of disorientation or entanglement within the helicopter occurred. Fifteen of these instances occurred in the absence of illumination. In eight of these instances, the divers used a stand-by emergency breathing device to help get themselves out of difficulty. The divers strongly recommended the availability of a breathing device as an egress aid.

A questionnaire of a type attributed to Epstein and Fenz [1965] was administered to the subjects to determine the relative levels of anxiety experienced during the

varying conditions of the experiment. The divers showed a decrease in anxiety from daylight to night conditions, but this was attributed to the fact that the initial exposure to the device was during daylight conditions and that the subjects were all highly qualified and well trained in a wide variety of underwater experiences, including night diving. Additionally, the divers reported a decrease in anxiety across the three-day experimental period.

Finally, it was determined, by the use of the aforementioned questionnaire, that the most stressful event of the ditching simulation consisted of inversion while the hulk sank (i.e. being strapped into a seat upside-down while sinking).

B. PHYSICAL FITNESS AND PERFORMANCE IN STRESSFUL SITUATIONS

Two studies relating physical fitness to performance in stressful situations were identified. One study examined personnel undergoing Army Airborne parachute training while the other dealt with Navy men in Underwater Demolition Team (UDT) training.

1. Prediction of Success and Fear in Airborne Training

A sample of 3,812 Airborne students including 2,187 enlisted personnel, 362 officers and 1,263 Reserve Officer Training Corps and Military Academy cadets was examined in an attempt to relate success in parachute training to individual physical fitness [Dyer and Burke, 1980]. Fear

levels for critical aspects of airborne training were also obtained from many of the successful personnel (unsuccessful personnel were not mentioned).

It was found that running performance on a two-mile run was a strong predictor of Airborne training success. Success was also found to be strongly related to the sex of the trainee, as were officer, enlisted or cadet status. Overall, males were more successful than females while cadets were found to be more successful than officers who were, in turn, more successful than enlisteds. Poor running performance was found to be related to low motivation, low fitness and previous injuries. For those personnel reporting fear levels, a small portion of the variance (ten per cent) in fear levels was predicted by running performance with faster runners reporting less fear.

2. Prediction of Performance in Stressful Underwater Demolition Training

This study, described by Gunderson, Rahe and Arthur [1972] examined the relationships between physical fitness test performance, response on two health questionnaires (the Cornell Medical Index and the Health Opinion Survey) and success in UDT training. The subjects in the study were 293 Navy enlisted men and 94 officers.

A double cross-validation design was employed using two sub-groups of 146 and 147 subjects. It was found that physical fitness test scores (for sit-ups, pull-ups and

squat-jumps), age and questionnaire responses (dealing with emotional symptoms) were predictive of success in training. In particular, those subjects showing better fitness were more successful (which was suspected due to the nature of strenuous UDT training). Among enlisted men, ages between 20 and 21 were predictive of success (with older and younger subjects showing less success) while emotional symptoms were related to higher failure rates. Officer subjects showed less success as age increased while no predictive value was attributed to emotional symptoms. Success rates for officer and enlisted subjects were 64 per cent and 49 per cent, respectively.

C. TECHNIQUES FOR MEASURING STRESS

The literature contains a wealth of information regarding stress measurement. The three major ways to examine stress are through the use of questionnaires, physiological measures and behavioral measures. Each of these approaches to stress measurement will be discussed independently below.

1. Subjective Stress Questionnaires

Some of the most notable results gathered relating subjective stress to actual performance were obtained in conjunction with the studies carried out by Berkun [1963] and summarized by Watson [1978]. On a series of simulated "emergency" tasks, Berkun found that the subjective stress level reported by experimental subjects was related to

actual performance levels attained on the tasks. The tasks themselves varied from filling out an "emergency data form" during a simulated aircraft emergency to repairing a radio transmitter under "live fire" to a mad ambulance race to save the life of a simulated accident "victim." In all cases, higher subjective stress was related to poorer performance. Also, during the stressful situations, raw recruits reported higher levels of stress than experienced troops while the experienced troops showed higher levels of performance.

As previously noted, Ryack et al [1979] used subjective stress scales to determine anxiety levels over the course of training in an aircraft ditching simulator and to identify the most stressful aspects of the simulated ditching. While specific anxiety versus performance data was not presented, it was shown that a decrease in anxiety and an increase in performance occurred as training progressed.

2. Physiological Measures of Psychological Stress

Many physiological stress measures are discussed in the literature, including blood content, urine content, metabolism, electro-encephalogram, galvanic skin response, blood pressure, respiration, body temperature and heart (pulse) rate [Singleton, 1973]. All of these measures, and others, are well established as indicators of both psychological and physiological stress. Berkun [1963] showed

relationships between subjective stress and hormone excretion, thereby providing validation for his subjective stress measures.

It must be noted that all of the physiological measures of stress mentioned above are intrusive in nature in that physical or electrical contact must be maintained with the subject during or immediately after the stress is imposed. Furthermore, some measures cannot easily differentiate between psychological and physical stress so that, in a situation which is both physically and mentally stressful (as when running away from a dangerous situation), the response cannot be attributed to either physical or psychological stressors.

3. Behavioral Measures of Stress

Behavioral measures of stress, aside from questionnaire results, deal mainly with observable behavior which can be related to psychological stress. Among these measures are hand tremor, error rate on some specified task, reaction time, etc. Many of these are described by Singleton [1973] and Watson [1978].

D. HUMAN PERFORMANCE UNDERWATER

From the literature, the two essential elements in human performance underwater are the psychological and physiological. The psychological aspects of human performance underwater which are considered germaine to the present

study will be examined first.

1. Psychological Aspects of Performance Underwater

Panic and a decrement in reasoning abilities are considered to be critical in the study of aircraft crashes at sea. Inability to breathe, poor vision, and the general shock and danger of a ditching may be overwhelming in their effects upon a human subject. Egstrom and Bachrach [1971] note that most divers who die in accidents are found still wearing weight belts, tanks containing air, masks and un-inflated buoyancy vests. Additionally, they state that individuals can expend near maximal effort for less than one minute and become so exhausted that they are unable, from the psychological point of view, to carry out simple actions that might save their lives (such as dropping the weight belt or inflating a life preserver).

It was noted, too, that panic (or extreme anxiety, at the least) leads to a decrement in the ability of divers to carry out simple sequential tasks which have not been properly practiced and "overlearned" by the individual. On the other hand, an individual on the verge of panic may fail to exhibit problem solving behavior and simply repeat a learned action over and over (i.e. pulling the reserve air handle) until exhaustion and loss of consciousness occur. This "perceptual narrowing" (i.e. focussing solely upon the specific task at hand) is a prime factor in fatal diving accidents [Egstrom and Bachrach, 1971].

From the foregoing discussion, it may be easily seen that the literature supports the potential for panic and a lack of intellectual performance in individuals who are suddenly thrust into a water survival situation. The very nature of anxiety in a life-threatening situation can be a threat to life, i.e. individuals who panic when faced with an emergency are less capable of saving themselves.

2. <u>Physiological Aspects of Performance Underwater</u>

The primary physiological aspects of human performance underwater in a ditching situation are breath-holding ability (and its related physiological phenomena) and the ability to locate an exit and egress successfully. The ability to inflate the life preserver, swim and maintain flotation are vital to survival after the egress, but will not be covered here because they are beyond the scope of this thesis.

a. Breath-Holding Ability

Studies of apneic (breath-holding) divers have shown several interesting physiological results. First, immersion of the face in cold water leads to an immediate decrease in heart rate (bradycardia) as noted by Bove, Pierce, Barrera, Amsbaugh and Lynch [1973]. It must be remembered, however, that strenuous physical activity of underwater escape or the psychological stress of the situation may offset this tendency. Further, after approximately two minutes of breath-holding, a second tendency for

the heart rate to slow is noted due to hypoxia [Landsberg, 1976]. Landsberg also wrote that one diver in his study exhibited central cyanosis after 135 seconds of apnea so that loss of consciousness could not have been far behind.

b. Disorientation

Disorientation underwater has long been observed in connection with blindfolded, night or turbid water dives. The human body, when immersed, is virtually weightless and this contributes to the tendency toward disorientation due to proprioceptive errors [Adolfson and Berghage, 1974]. Normal muscle tension which is required for balance in air may cause the human subject to, for instance, reach higher than normal when extending the arm into space. If blindfolded or otherwise deprived of visual information, the human immersed in water may be unable to locate familiar objects or fixtures because his perception of body location is altered by buoyancy.

Perception of the vertical is nearly impossible when immersed in water and deprived of vision, especially when the body has been rolled around or tumbled. This is due to negligible proprioceptive input (as seen above) and vestibular disorientation due to rolling or tumbling. If the subject is oriented off the vertical, the ability of the vestibular organs and otoliths to provide clues to vertical orientation is drastically reduced and, when inverted (head-down) provide very little information

[Adolfson and Berghage, 1974]. Furthermore, vestibular inputs due to rolling or tumbling motions may lead the subject to lose all orientation with respect to his position in a sinking vehicle unless he has maintained a stable tactual point of reference.

Finally, if the human loses his tactual point of reference while submerged and is deprived of vision, he may be unable to reorient himself inside the vehicle. Geographical position (which in this case represents position inside the vehicle) may be lost due to drifting, swimming in a "veering" path or inability to recognize tactual clues without vision [Adolfson and Berghage, 1974].

Panic, as noted previously, can only serve to degrade the performance of the human in attempting to re-establish his position inside the vehicle.

E. HYPOTHESES

Seven hypotheses were formulated based upon the survey of the literature and previously reported behavior in the 9D5 device.

1. Physical Fitness is Related to 9D5 Performance

The study of Army Airborne training behavior suggested that measures of physical fitness might be good predictors of performance in the 9D5 device. This is also supported by the Underwater Demolition Team training study which related physical fitness to success. As previously

noted, several physical fitness scores for 9D5 trainees were available, and it is hypothesized that subjects who were in better physical condition (as measured by those tests) would do better in the 9D5 device.

2. Swimming Test Grades May Be Used to Predict 9D5 Performance

It is hypothesized that subjects who failed one or more swimming tests prior to taking the 9D5 training would have more difficulty in the 9D5 than subjects who did not fail swimming tests (or who were exempted).

3. Poor 9D5 Performance is Related to Anxiety

The stressful nature of underwater egress training in general suggested that some decrement in performance might have been experienced due to anxiety or panic in a breath-holding situation. Earlier comments on diver performance during life-threatening emergencies also suggested this hypothesis.

4. Seat Position Influences 9D5 Performance

The previous study of underwater egress performance stated that egress times varied depending upon the location of the seat within the device. It is hypothesized that some 9D5 seat positions were more difficult than others with respect to egress performance.

5. The 9D5 Device Produces Disorientation

It was reported by 9D5 instructors that many subjects appeared to be disoriented during the training. The

sinking, rolling motions of the 9D5 device (which will be described later) should be sufficient to induce disorientation, according to the literature surveyed. The fact that trainees were required to be blindfolded during some of the 9D5 rides would suggest the possibility of vestibular disorientation.

6. Biographical Information Can Be Used to Predict 9D5 Performance

Boyles [1967] developed a "Background Activities Inventory" that was used to predict success in helicopter pilot training. It was hypothesized that a similar prediction could be made for the 9D5 device trainees based upon biographical information alone.

7. Near Drowning Experiences Are Correlated with Difficulty in the 9D5 Device

It was suggested that an aversion reaction due to a previous near-drowning experience could interfere with 9D5 performance. This hypothesis is related to Hypothesis Six stated above.

F. STRATEGY

In order to test the hypotheses stated above, two complementary strategies were formulated.

1. 9D5 Performance Data and Other Objective Measures of Success

It was decided that eight different performance measures for each subject would be examined in an attempt to find a good predictor of success in the 9D5 device. The

first of these, of course, would be the 9D5 training records themselves. These records contain data on both the number of failures for each subject and the reason for failure on each training ride.

The remaining measures of fitness will be described in section III-B. It can be noted here, however, that these other measures of fitness were all tests of swimming skill or running ability.

2. Questionnaire Data: Subjective Stress and Biographical Information

A measure of psychological stress was considered essential to the research on 9D5 performance. For reasons that will be stated in section III-D, a questionnaire was the only instrument available for gathering information on subjective stress. A questionnaire based upon the modified Epstein-Fenz scale of the study by Ryack et al was adapted for use in the 9D5 training scenario. Additionally, the simple "background" questionnaire was developed and administered along with the "stress" questionnaire in order to address Hypotheses Six and Seven.

G. SUMMARY

The seven hypotheses listed in section E above are directly related to panic, performance under stress, performance underwater and training effectiveness. Examination of these hypotheses in light of the literature previously surveyed and the objective and subjective data gathered in

conjunction with 9D5 training should answer the basic questions addressed in Chapter I.

III. APPARATUS AND PROCEDURE

In this chapter, the 9D5 device, the subjects and their descriptive statistics, the questionnaire used and the 9D5 training session will all be described. The results obtained and an analysis of the data gathered will be presented in Chapter IV.

A. THE 9D5 DEVICE

The proper nomenclature for the 9D5 device is, "Multi-Place Universal Underwater Egress Trainer." The particular device used in this study was the first installed by the United States Navy. The device is 18 feet long, seven feet in diameter, and is suspended approximately six feet above a 15 foot deep pool. The entire assembly is located inside a heated building.

Six seats are installed in the 9D5 device but, for safety reasons, only four (two in the front and two of four in the back) are used at any time. The two forward facing seats simulate a helicopter cockpit while the four seats in the back are inward facing (as do troop seats in fleet aircraft). The device does not simulate any particular aircraft (fixed-wing or helicopter) but, rather, is designed to provide general training in the mental and physical processes required to escape from a sinking multi-place air-

craft [Naval Aviation News, July 1976].

The device is powered hydraulically to prevent electrical shock hazards and its movements are controlled by an operator stationed above the pool on a platform attached to the 9D5 support structure. At the option of the operator, the device may be rolled up to 180° in either direction. By actual observation during training sessions, it was determined that the device takes approximately ten seconds to descend from its cradle to the surface of the water. An additional seven seconds are required to roll 180° (or less) and completely submerge.

Figure 1 is a photograph showing the 9D5 device suspended from its cradle in the boarding position. The cockpit area is to the right in this picture.

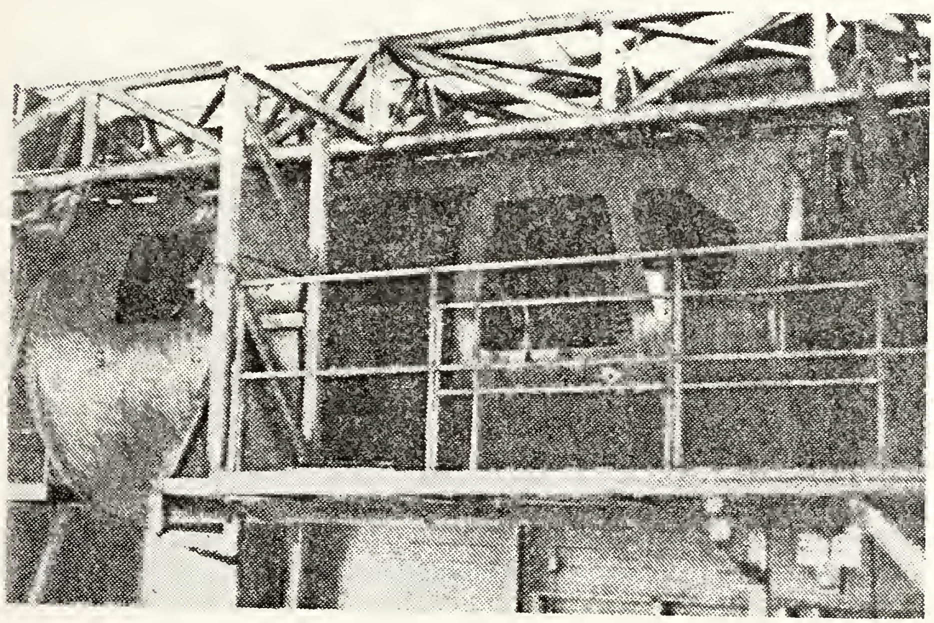

Figure 1. THE 9D5 DEVICE AND ITS SUPPORTING STRUCTURE

Figure 2 shows the device with subjects aboard just as descent is begun. Figures 3 through 6 present views of the device impacting the water, rolling to the right, and submerging to its final position.

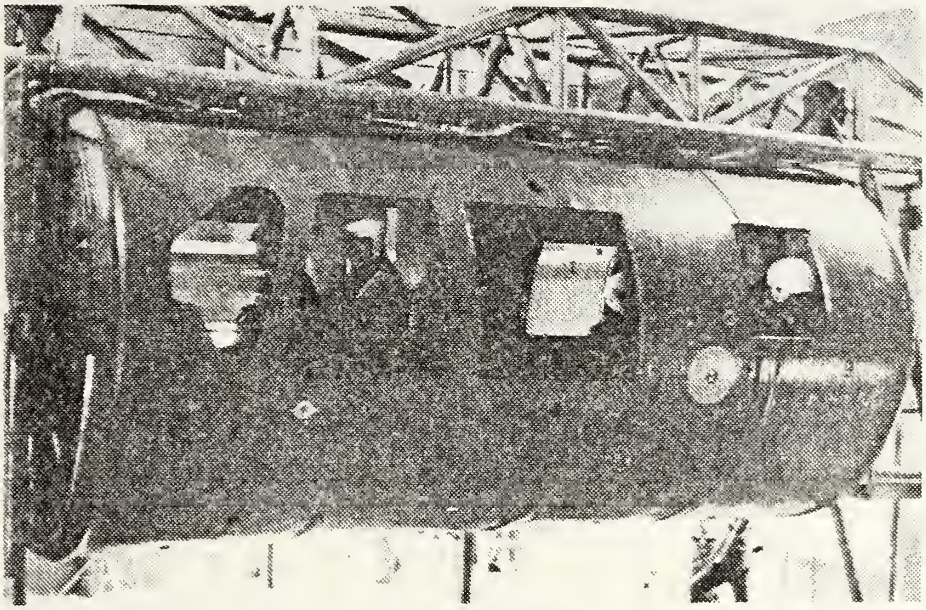

Figure 2. SUBJECTS ABOARD THE DEVICE AS DESCENT BEGINS

The photographs represent the normal operating sequence of the 9D5 device. The direction of roll is essentially random, as selected by the operator, on each ride. Although no set procedure for selecting the direction of roll is prescribed, the subjects have no reason to expect a roll in any particular direction since the controls are shielded from view.

Two safety divers observe the subjects at all times, and

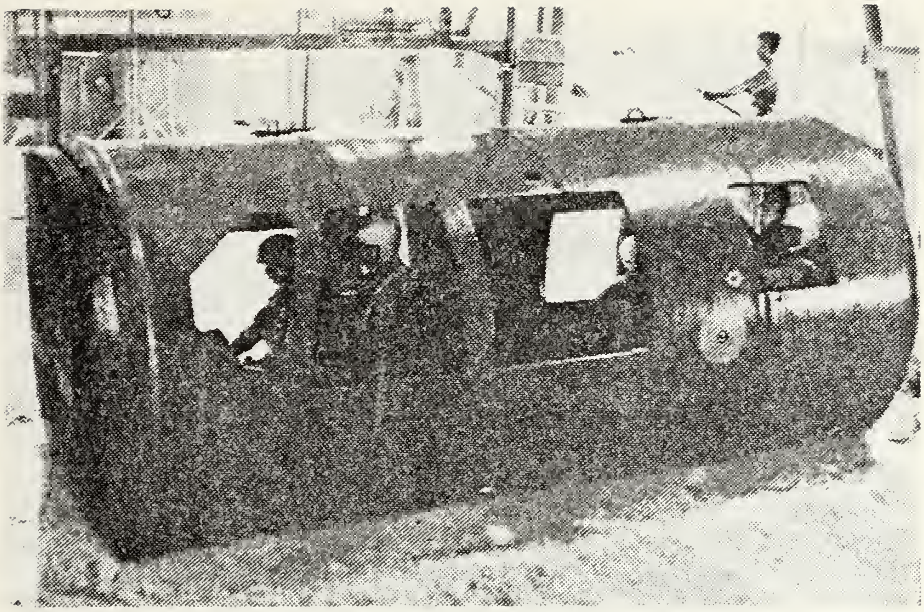

Figure 3. THE 9D5 DEVICE AT THE INSTANT OF WATER IMPACT

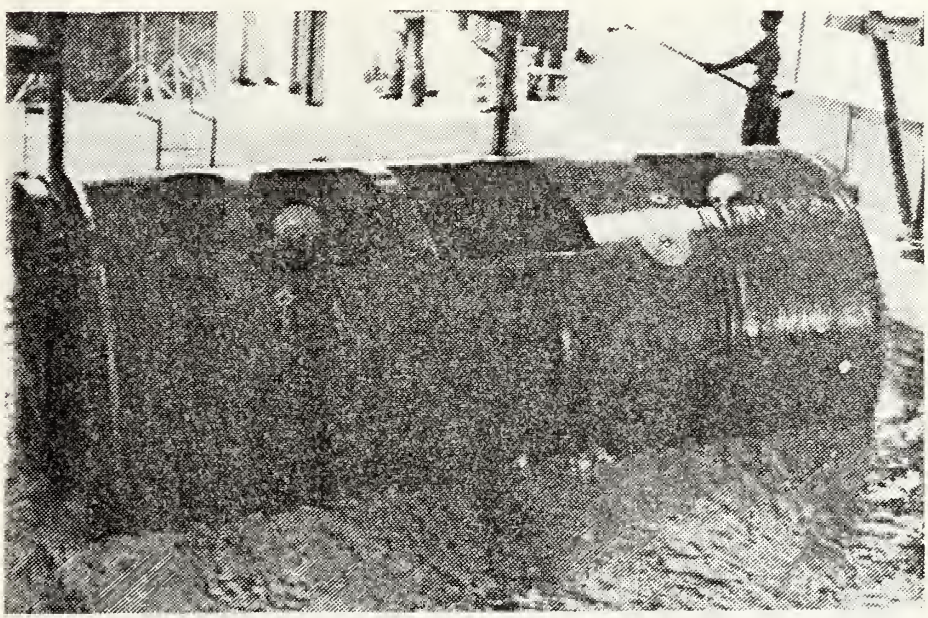

Figure 4. THE 9D5 SINKS WHILE ROLLING TO THE RIGHT

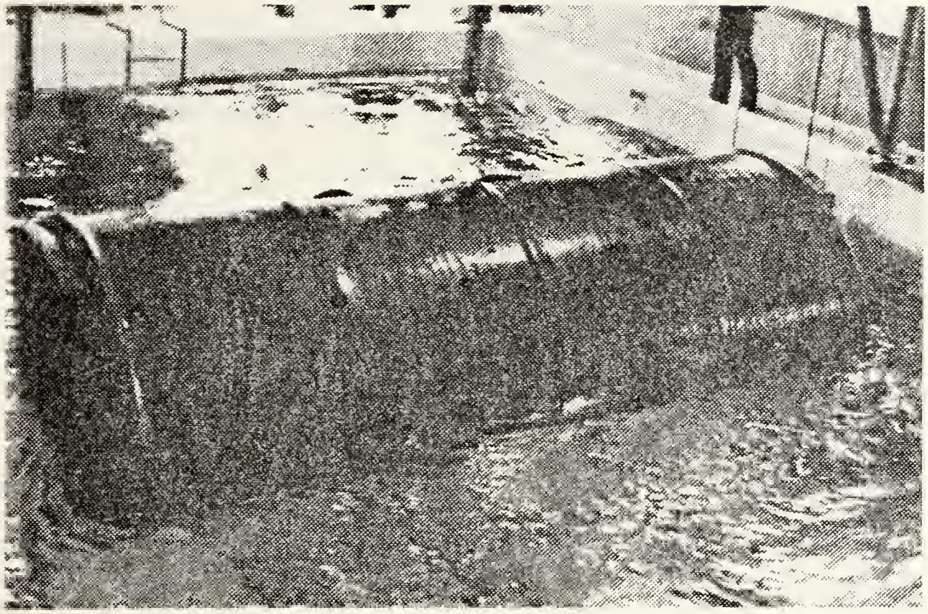

Figure 5. THE 9D5 DEVICE AFTER APPROXIMATELY 90° OF ROLL

Figure 6. FINAL POSITION OF THE 9D5 DEVICE AFTER SINKING

emergency breathing equipment plus an emergency retraction system ensure the safety of the subjects. Additionally, a Navy Hospital Corpsman is present for all training and additional medical attention can be obtained in a matter of minutes.

B. SUBJECTS

The subjects for this study were drawn from the usual Water Survival Training classes conducted at Naval Aviation Schools Command. All of the subjects under study were undergoing their initial qualification rides in the 9D5 device. No attempt was made to draw a true random sample from the population of personnel exposed to 9D5 training but, rather, an attempt was made to obtain data on an equal number of Navy Officers (NAVY), Marine Corps Officers (USMC), Enlisted Aircrewman Candidates (ENL) and Aviation Officer Candidates (AOC). As such, the subjects in each of these four service groups represent merely a "snapshot" of the population tested during the months of June through October, 1980.

Data sets were obtained for 267 subjects. All subjects in this study were males participating in the initial qualification training required before proceeding on to actual flight training. (While enlisted subjects do not go on to actual flight training as pilots or flight officers, they are still required to complete all physical fitness, swim-

ming and survival training prerequisites.)

Of the 56 subjects identified as Navy Officers, 47 were Ensigns (O-1), eight were Lieutenants (Junior-Grade) (O-2), and one was a Lieutenant (O-3). The 76 Marine Corps Officers were represented by 74 Second Lieutenants (O-1) and two First Lieutenants (O-2). The Navy Enlisted men included two E-1s, 31 E-2s, nine E-3s, 12 E-4s, eight E-5s and two E-6s, for a total of 64. Aviation Officer Candidates were not further classified and comprised a total of 58 subjects. Four subjects were not identified with any of these service groups due to problems with the data.

A number of physical fitness tests and swimming tests were completed by each subject before commencing 9D5 training. The results of those tests which might be related to the hypotheses stated in Chapter II are presented below.

1. Mile-Swim Times

Each subject was required to swim a distance of one-mile while wearing a flight suit. The test was conducted in an indoor swimming pool and closely observed (by instructors) to ensure the subjects' safety and to accurately record, to the nearest minute, the time required for each subject to complete the swim. Any swimming stroke could be used so long as the subject completed the one-mile distance in 90 minutes or less. Approximately 30 subjects took the test simultaneously.

If a subject could not complete or had not

completed the one-mile distance before 90 minutes had elapsed, he was required to take remedial swimming classes and be retested until he passed the test. Failure to pass the one-mile-swim test (or any of the tests to be described below) eventually would lead to disenrollment from flight training.

Table I is a summary of mile-swim times for each service group. In order to identify differences among groups, a one-way analysis of variance was performed and is summarized in Table II.

Table I. MILE-SWIM TIME IN MINUTES FOR EACH SERVICE GROUP

Service Group	Mean	Std. Dev.	Min.	Max.
NAVY	58.05	9.95	40.0	89.0
USMC	58.53	10.28	38.0	86.0
ENL	67.60	7.98	45.0	85.0
AOC	59.55	13.37	36.0	86.0

Table II. ANALYSIS OF VARIANCE FOR MILE-SWIM DATA

Source	D.F.	Sum of Squares	Mean Squares	F	Prob
Between Groups	3	3832.87	1277.62	11.59	.0000
Within Groups	256	28224.67	110.25		
Total	259	32057.53			

A significant difference was found among the four service groups ($p < .0001$). Further testing revealed that the enlisted subjects' mile-swim times were, overall, different from all the other service groups ($p < .05$; Tukey's Honestly Significant Difference Test). A cursory examination of Table I shows that enlisted subjects, on the

average, took approximately eight minutes longer to swim a mile than the other groups of subjects.

2. Cross-Country Run Times

All subjects were required to complete a run of 1.6 miles in 11 minutes and 39 seconds or less. The run proceeds across varying types of terrain with different degrees of difficulty from wooded hills to sand pits. Completion times were recorded to the nearest second. Failure resulted in remedial training and retesting. Table III is a summary of cross-country run times, in seconds, while Table IV presents a one-way analysis of variance for the data.

Table III. CROSS-COUNTRY RUN TIMES, IN SECONDS

Service Group	Mean	Std. Dev.	Min.	Max.
NAVY	632.71	52.81	505.0	810.0
USMC	620.72	39.88	532.0	695.0
ENL	652.48	48.89	570.0	826.0
AOC	605.03	46.29	506.0	711.0

Table IV. ANALYSIS OF VARIANCE FOR CROSS-COUNTRY RUN TIMES

Source	D.F.	Sum of Squares	Mean Squares	F	Prob
Between Groups	3	73797.49	24599.16	11.17	.0000
Within Groups	258	568097.88	2201.92		
Total	261	641895.31			

A one-way analysis of variance showed that differences existed among the four service groups ($p < .0001$). Differences were also found between NAVY and AOC, ENL and AOC and USMC and ENL ($p < .05$) using Tukey's Honestly Significant Difference procedure.

3. Obstacle Course Times

The obstacle course (consisting of vertical walls, etc.) had to be completed in 3 minutes and 48 seconds or less, with all timing done to the nearest second. A summary table for the four service groups under examination is presented below.

Table V. OBSTACLE COURSE TIMES, IN SECONDS, BY SERVICE GROUP

Service Group	Mean	Std. Dev.	Min.	Max.
NAVY	212.28	24.46	166.0	300.0
USMC	204.05	22.93	166.0	284.0
ENL	212.71	41.13	166.0	432.0
AOC	196.29	25.18	153.0	315.0

As in previous sections, an analysis of variance was performed and is presented as Table VI. Differences among the service groups were detected ($p < .0051$) with further analysis by Tukey's HSD test finding differences between NAVY and AOC and between ENL and AOC ($p < .05$).

Table VI. ANALYSIS OF VARIANCE FOR OBSTACLE COURSE TIMES

Source	D.F.	Sum of Squares	Mean Squares	F	Prob
Between Groups	3	11056.78	3685.60	4.364	.0051
Within Groups	257	217038.23	844.51		
Total	260	228095.00			

4. Other Swimming Tests

Each subject was required to take a number of swimming tests, some of which are examined here. A relatively

small number of failures was observed on each of these individual tests, so it was decided to use the total number of swimming test failures as a possible measure of overall adaptation to the water. This statistic was observed in order to examine the hypothesis that 9D5 performance can be predicted by swimming test grades.

The tests are described, individually, below. Before the tests are described, however, a summary table will be presented showing the observed performance of each service group.

Table VII. TOTAL SWIMMING TEST FAILURES, BY SERVICE GROUP

Service Group	None	One	Two	Three	Four	Exempt
NAVY	24	7	4	1	0	29
USMC	26	13	4	2	0	31
ENL	28	21	7	7	1	0
AOC	35	8	4	4	7	0
TOTAL	113	49	19	14	8	60

The "Exempt" category complicated the analysis of this particular data set. "Exempt" status was gained only by Navy or Marine Corps Officers who had previously been trained and tested, by virtue of service experience, and classified as first-class swimmers. Those officers who then passed a screening test at Naval Aviation Schools Command were exempted from further training and testing in all but the mile-swim test. In this respect, the various service groups are indeed different.

a. Mile-Swim Test

In this instance, the mile-swim test was treated as a pass-fail test. A failure on the mile-swim test would cause a score of one to be added to a subject's total swimming test failure score. Since mile-swim times of more than 90 minutes were not recorded, this was the only way of accounting for outright failures.

b. Swimming Strokes Test

This test consisted of swimming a distance of 200 yards continuously, while using the backstroke, sidestroke, breaststroke and the American crawl stroke for a distance of 50 yards each. Inability to complete the test satisfactorily (as judged by swimming instructors) resulted in a grade of "fail" which had to be made up through extra training and retesting. A failure resulted in the subject's test failure total being increased by one.

c. Tower Jump, Underwater Swim

The subject was required to enter the water from a ten-foot or higher tower in the manner prescribed for abandon-ship procedures. He then remained submerged and swam a distance of 50 feet without breaking the surface of the water. A subject failing this test received an additional score of one added to his total, and eventually passed the test before completing the water-survival course.

d. Treading Water and Drownproofing

Each subject was required to remain afloat

(while wearing flight clothing) for a period of 30 minutes by treading water and drownproofing, each for a set period of time. A failure was tabulated and totaled in the manner described for the other swimming tests.

C. DEVELOPMENT OF THE QUESTIONNAIRE

To test the hypotheses that; (1) subjective anxiety, (2) previous experience and (3) a near-drowning experience may have an effect on 9D5 performance, a suitable written instrument had to be devised. A copy of the questionnaire is included in Appendix B.

1. Measurement of Subjective Anxiety

Elements of the questionnaire used in the previous study [Ryack et al, 1979] of underwater egress performance were adapted to this scenario. A sequence of 15 items, describing the 9D5 training ride, was presented to the subjects following the training. Each item was accompanied by a scale from "0" to "10" upon which the subject was to rate his relative anxiety during that particular part of the ride. A "0" grade would indicate complete calm while a grade of "10" would indicate the most anxious event or events of the training. Figure 7 is a specimen of this questionnaire element.

It would be desirable to administer this questionnaire to each subject after each ride in the device, however, this was not physically possible. The wet pool environment, lack

9D5 QUESTIONNAIRE

The 15 items listed immediately below describe the sequence of events you experienced during your 9D5 training. Read over the 15 items and decide which one was the most anxiety-producing event for you. Circle the number 10 on the scale to the right of your most anxiety-producing event. Then, rate the other 14 items according to how you felt during each event. For example if you experienced as much anxiety as in the event you chose above, circle the number 10. If you felt no anxiety at all, circle the number 0. You may use each number as often as you like.

		Perfect calm — Your greatest level of anxiety
1.	Before the training began ----------------	0 1 2 3 4 5 6 7 8 9 10
2.	Waiting to board the trainer -------------	0 1 2 3 4 5 6 7 8 9 10
3.	Boarding the trainer ---------------------	0 1 2 3 4 5 6 7 8 9 10
4.	On board waiting for descent -------------	0 1 2 3 4 5 6 7 8 9 10
5.	While descending -------------------------	0 1 2 3 4 5 6 7 8 9 10
6.	While sinking ----------------------------	0 1 2 3 4 5 6 7 8 9 10
7.	While rolling over -----------------------	0 1 2 3 4 5 6 7 8 9 10
8.	While counting 5 to 8 seconds ------------	0 1 2 3 4 5 6 7 8 9 10
9.	While releasing the seat belt ------------	0 1 2 3 4 5 6 7 8 9 10
10.	While finding the exit -------------------	0 1 2 3 4 5 6 7 8 9 10
11.	While pulling through the exit -----------	0 1 2 3 4 5 6 7 8 9 10
12.	While swimming to the surface ------------	0 1 2 3 4 5 6 7 8 9 10
13.	Reaching the surface ---------------------	0 1 2 3 4 5 6 7 8 9 10
14.	Waiting for the next ride ----------------	0 1 2 3 4 5 6 7 8 9 10
15.	Now --------------------------------------	0 1 2 3 4 5 6 7 8 9 10

Figure 7. 9D5 RIDE SEQUENCE ANXIETY QUESTIONNAIRE

of writing surfaces, and the requirement to not interfere with the conduct of the training sessions necessitated a post-training questionnaire only. Since it was desirable to gather information across all four training rides, a second section of four items was presented below the 15 items mentioned above. Those four items, presented in the same format and with the same scale as items one through 15, asked the subject to rate his anxiety on each of the four training rides. Figure 8 is an example of this additional

questionnaire element.

The four 9D5 rides are briefly described below. Using the same scale you used for items 1 through 15, mark each ride to indicate the highest level of anxiety you felt during each ride. You should have at least one grade of 10 on one of the rides since you marked at least one "10" above. For example, if you experienced your greatest anxiety on ride 2, then ride 2 should get a grade of 10. Rate the other 3 rides on the scale of 0 to 10 as you did above. You may use the same number as often as you like.

	Perfect Calm — Your greatest level of anxiety
Ride one (window exit) -------------------	0 1 2 3 4 5 6 7 8 9 10
Ride two (door exit) ---------------------	0 1 2 3 4 5 6 7 8 9 10
Ride three (window exit wearing goggles) -	0 1 2 3 4 5 6 7 8 9 10
Ride four (door exit wearing goggles) ----	0 1 2 3 4 5 6 7 8 9 10

NAME______________________ SSN_____-____-_______ Date_______1980

Figure 8. ANXIETY SCALE COMPARING RIDES ONE THROUGH FOUR

The subject was instructed to assign a value of "10" to at least one of items one through 15, and to one of the items describing the four training rides. In this way, both the most stressful rides and the most stressful elements of the most stressful rides were to be identified.

Since the subjects were instructed to assign a value of "10" on both sections of the questionnaire, possible absolute measures of stress could not be obtained. In order to correct this deficiency, another questionnaire item was devised to measure subjective anxiety on an absolute scale from "0" to "100" where a grade of "0" indicated complete calm and a grade of "100" indicated a state of panic. This last item, represented in Figure 9, was separated from the foregoing 19 items by a biographical questionnaire (which will be examined below). The rationale

for separating the "absolute" stress scale from the "relative" stress scale was to shift the subject's attention away from the "0" to "10" scale so that the possibility of mixing the grading scales could be reduced.

9D5 QUESTIONNAIRE

Disregard the scales used earlier. On the scale below, circle the number which you feel best describes the greatest level of anxiety you experienced at any time during your 9D5 training. On this scale, 0 (ZERO) indicates a state of complete calm and relaxation. 100 (ONE-HUNDRED) indicates a state of extreme anxiety (panic). For example, if you feel that your greatest level of anxiety during the 9D5 training was near-panic, you should mark a number close to 100. If you felt no more anxiety than you would feel while relaxed and comfortable in your own home, you should mark a number close to 0. You should not make more than one mark on the scale.

Complete calm ______________________________ Extreme anxiety
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

Figure 9. THE "ABSOLUTE" ANXIETY SCALE

Complete instructions for filling out the questionnaire were printed on the questionnaire form. All instructions were designed such that no verbal interaction between the researcher and the subjects was required. Pilot studies were conducted to ensure the clarity of the instructions and to finalize the questionnaire format before the research began.

2. Biographical Information

A great deal of biographical information is recorded on personnel who enter flight training. Most of that information, however, was not accessible during the course of this research due to limitations in man-power, time and the touchy nature of personal data. Given these limitations,

a short biographical questionnaire was developed to determine previous participation by the subjects in water sports. Figure 10 is a specimen of the biographical questionnaire.

9D5 QUESTIONNAIRE

NAME______________________________ SSN______________________ Date ________1980

Please place an "X" beside all of the activities listed below that you have actually pursued for a period of six months or longer.

___Certified scuba diver	___Primitive camping
___Salt-water skin diving	___Boy Scouts/Girl Scouts
___Water skiing	___Cross country or marathon running
___Red Cross Senior Life-saver	___Organized competitive swimming
___Sky diving or parachuting	___Part-time jobs during high school
___Pilot training	___College
___Competitive automobile racing	___Church sponsored yough groups
___High school varsity sports	___Cave exploration (spelunking)

If you have ever been involved in a true life-threatening situation, please describe it briefly:____

____

____

What is your present age? _____

In what town or city and state did you live for the longest time as a child?

____

Figure 10. THE BIOGRAPHICAL QUESTIONNAIRE

In addition to water-sport activities, it was desirable to determine the ages of the subjects under study.

Since date-of-birth information was not already provided on written records within the 9D5 training syllabus, it was requested on the biographical questionnaire.

The final data element desired from the biographical questionnaire was related to near-drowning experiences. Rather than ask a leading question concerning drowning, the subjects were requested to briefly describe any true life-threatening experiences previously encountered. The near-drowning experiences could then be culled and tabulated.

The reader has probably noticed that several seemingly unrelated items are addressed on the biographical questionnaire, including participation in "Church sponsored youth groups," etc. These items were included merely as noise to ensure that the questionnaire was actually being read and filled out with some measure of candor. Additionally, the interest was solely in whether or not the subjects reported participation in stressful or potentially dangerous water activities, not in the total number of different activities listed on the form.

3. A Word of Caution

The questionnaire described above was an adaptation of the modified Epstein-Fenz scale used by Ryack, et al [1979] and reflects the principles of questionnaire design. It was considered a reasonable instrument for application in this study and had the benefit of a pilot utilization study. However, the reliability and validity of this question-

naire has not been established.

The completion and submission of questionnaires by subjects was voluntary. Standard Privacy Act and Volunteer Consent forms were completed before questionnaire data were gathered since names were used to relate questionnaire data to objective data for analysis. Inability to require participation in the study complicated subsequent analysis of the subjective data, so that results using subjective data must be examined carefully with an eye toward sample sizes and the characteristics of the "volunteers" and "non-volunteers."

D. DESCRIPTION OF A TYPICAL 9D5 TRAINING SESSION

The 9D5 training session begins with a motivational sound-on-slide presentation which gives statistics on ditching survival rates, etc., and the philosophy behind the training to follow. Trainees then examine the device in preparation for the next phase of briefing.

A water survival training instructor presents a verbal briefing covering the proper procedures to be used in the 9D5 device. (Appendix C outlines specific procedures for each possible seat-ride combination.) Performance criteria for the various seat-ride combinations to be experienced are explained in detail and shown graphically with the aid of a slide projector. When this briefing is completed the trainees have been thoroughly prepared for the events to

come. During this briefing, trainees are assigned to groups of four via a simple training roster that is passed around the room and filled in by the subjects. Each group of four takes all 9D5 rides together.

When the briefing is completed, the subjects proceed to the pool area and don complete flight gear of the types they will be using in the fleet. Helmets are worn also, but these are basically football helmets adapted for use in the water. When properly attired, the first group of trainees is briefed again and allowed to ask questions concerning the device. The subjects then board the trainer and are assisted in strapping into their seats by instructors. Again, questions are allowed while strapping in and instructors quiz the trainees to make sure that procedures are understood.

The instructors then clear the 9D5 device and the operator causes the machine to go through its descending, rolling cycle. The trainees inside the device perform their egress and then swim to the side of the pool. Divers in the pool communicate with another instructor via an umbilical telephone device and report the grade performance for each subject. Finally, the subjects are debriefed on their performance and sent to wait for their next ride. In the meantime, another group has been briefed and seated in the device to follow the same sequence of events.

There are four different rides in the 9D5 device. Ride

one is accomplished by egressing from the subject's nearest exit in accordance with procedures previously covered in briefings. Ride two requires the subjects to egress via the main entry door. Ride three is exactly like ride one, except that the subjects are blindfolded to simulate night-time conditions. Ride four is exactly like ride two with the addition of blindfolds. All groups complete ride one before the first group moves on to ride two, and this pattern is repeated for rides three and four. Finally, the seats in the 9D5 device are numbered from one to four for training purposes and each subject moves "up" one seat on each subsequent ride. For example, a subject who takes ride one in seat three will take ride two in seat four, etc., until he has completed four rides, each in a different seat.

Ride four is the checkride for each subject. Ride four must be completed exactly in accordance with procedures in order to pass the training. If a subject fails to follow proper procedures or becomes lost in the device while blindfolded, he fails ride four and must retake the ride. Two retakes are allowed on any one day. If the subject fails to complete the checkride by ride number six, he must repeat the training at a later time.

When a subject completes the checkride successfully, he is allowed to shower and change into his uniform. Successful trainees then fill out a critique sheet to complete the training evolution.

E. DATA COLLECTION CONSIDERATIONS DURING THE TRAINING

It was originally hoped that the researcher would be able to observe the subjects underwater during their egress in order to time their belt-release-to-egress performance. (This was the metric used by Ryack et al, 1979.) Safety considerations and possible interference with divers stationed in the pool prevented this.

The only easily obtained measures of performance during the 9D5 training were those already being collected by divers in the pool, i.e. the grades assigned to each subject on each ride. All rides were graded and any error that would result in a checkride failure was defined, for the purposes of this study, to constitute a failure. The specific grades assigned and their meanings are illustrated in Table VIII.

Table VIII. POSSIBLE 9D5 GRADES

Grade	Meaning or Explanation
SB	"Slide Bar" -- failed to simulate hatch opening
ER	"Early Release" -- released seat belt prematurely
NP	"No Pull" -- did not "pull" out using arms only
WH	"Wrong Hole" -- used wrong exit
PG	"Pulled Goggles" -- removed blindfold
PA	"Panic" -- panicked and failed to follow procedures
DR	"Diver Rescue" -- helped by safety divers
DO	"Dropped at Own request" -- voluntarily dropped out
NO	"NO errors" -- ride passes successfully

Regarding grading criteria for the codes assigned on each ride, only one, "Early Release" is at all subjective on the part of the divers. All others are observed and judged on an easily discernible yes-or-no basis including "Panic" which is indicated by a complete lack of compliance with procedures while thrashing around, etc. The specific criterion for an "Early Release" failure is that the subject did not wait five to eight seconds (to simulate waiting for water to stop rushing into the sinking aircraft) before releasing the seat belt. This time period is merely judged by the divers rather than measured with a timepiece. Appendix C contains a task-analysis based description of the prescribed 9D5 egress procedures and should be consulted if a specific description is desired.

Intrusive physiological measures could not be used during this study. In the first place, blood tests, urine samples, etc. would have taken too much time during the course of normal training. Electrical instrumentation would have presented a shock hazard and potential problems with cable entanglement. In the second place, funding, medical personnel and instrumentation were not available. Hence, the post-training questionnaire was employed as the only specific measure of psychological stress in this study.

F. CONDUCT OF "EXPERIMENTAL" 9D5 TRAINING SESSIONS

The only difference between a typical training session and the training sessions involved in this study are those related to completion of the questionnaires. Prior to the initial briefing, the researcher or another officer explained the nature of the study at hand to the subjects. The training session then was carried out as usual without further intrusion.

Upon completion of the training, all subjects were asked to complete the questionnaire whether they had been successful or not in passing the training. In this way, approximately 208 sets of full data (out of 267 subjects) were obtained. However, objective grade data for all 267 subjects was available.

IV. RESULTS AND CONCLUSIONS

All descriptive data, 9D5 grade data, and subjective questionnaire data was analyzed in order to address the hypotheses previously stated. Unless otherwise noted, all statistical results (significant differences, etc.) were tested using a procedure proposed by Bruning and Klintz [1968] for testing differences among proportions.

A. 9D5 PERFORMANCE STATISTICS

The data examined in this section was gathered during the 9D5 training sessions in which the 267 subjects participated. As stated earlier, all "ride" data was in the form of a grade code assigned by the divers observing the subjects during the egress portion of each training ride.

1. Number and Sequence of Failures

Both the number and sequence of failures for each subject were of interest. There are 16 possible combinations of ride versus failure interactions, i.e. failure on rides one and two, one and three, one and two and four, etc. With the exception of those subjects who failed no rides at all, no particular pattern or relationship was observed which might distinguish one service group from another. It was therefore decided to investigate the possible relationships which might exist between service groups when total

9D5 failures were tabulated by service group. Table IX summarizes these results.

Table IX. NUMBER AND PERCENTAGE OF PERSONNEL IN EACH SERVICE GROUP WHO FAILED NONE, ONE, TWO, THREE, OR FOUR RIDES

Service Group		None	One	Two	Three	Four	N
NAVY	Number	12	23	21	7	2	65
	Per cent	18.5	35.4	32.3	10.8	3.1	
USMC	Number	16	17	25	12	6	76
	Per cent	21.1	22.4	32.9	15.8	7.9	
ENL	Number	8	19	22	9	6	64
	Per cent	12.5	29.7	34.4	14.1	9.4	
AOC	Number	23	20	11	3	1	58
	Per cent	39.7	34.5	19.0	5.2	1.7	

A Chi-square Test for independence among service groups and total failures showed a significant difference from that which would be expected by chance alone ($p < .0165$). This indicates that some systematic relationship exists which explains the differences in observed performance among the four service groups. In simpler terms, this says that some groups performed better than others. Note that, for example, Aviation Officer Candidates had one or fewer failures in 74 per cent of the subjects observed while among Enlisted Aircrewman Candidates 58 per cent of the subjects observed had two or more failures.

2. Estimated Probabilities of Failure in the 9D5

This section presents estimated probabilities of

failure determined from observed proportions of failure in the 9D5 device (Table X). Based upon a sample size of 267 subjects, the statistics were not broken down by service group. The relatively small number of subjects in each group precluded the usefulness of computing estimated probabilities for each service group.

A few comments on notation are in order. A conditional probability can be represented as $P(A|B)$ and is read, "The probability that event A will occur given that event B has already occurred." For example, in Table X, item ten is read, "The probability that ride four will be failed, given that rides one, two and three were previously failed, is .65 (or 65 per cent)." The numbers in parentheses following each item represent the number of subjects out of 267 who fell into that category. Again using item ten as an example, "(n=23)" means that 23 subjects failed rides one, two and three. Items one through nine in Table X are not conditional probabilities, and are read simply as (for example), "The probability of failing ride number one is 47 per cent."

The primary interest was in the proportion of subjects who failed rides one and four. Ride one is an indicator of performance in subjects who have received only a briefing prior to the egress experience. Ride four is important because performance there is indicative of the effectiveness of the training on rides one, two and three.

Rides two and three were examined for significant trends in performance, as well.

Table X. ESTIMATED PROBABILITIES OF FAILURE FOR SELECTED 9D5 RIDES

1. P(fail ride 1) = .47 (n=267)
2. P(fail ride 2) = .378 (n=267)
3. P(fail ride 3) = .344 (n=267)
4. P(fail ride 4) = .28 (n=267)

5. P(fail at least one ride) = .77 (n=267)

6. P(fail ride 1 only) = .112 (n=267)
7. P(fail ride 2 only) = .079 (n=267)
8. P(fail ride 3 only) = .052 (n=267)
9. P(fail ride 4 only) = .052 (n=267)

10. P(fail ride 4 | failed 1, 2 and 3) = .65 (n=23)
11. P(fail ride 4 | failed 1 and 2) = .37 (n=30)
12. P(fail ride 4 | failed 1 and 3) = .27 (n=33)
13. P(fail ride 4 | failed 2 and 3) = .17 (n=18)

14. P(fail ride 4 | failed ride 1 only) = .25 (n=40)
15. P(fail ride 4 | failed ride 2 only) = .30 (n=30)
16. P(fail ride 4 | failed ride 3 only) = .22 (n=18)

17. P(fail ride 4 | failed ride 1 previously) = .357 (n=126)
18. P(fail ride 4 | failed ride 2 previously) = .376 (n=101)
19. P(fail ride 4 | failed ride 3 previously) = .337 (n=92)

An examination of items one through four in Table X indicates that an improvement in overall performance took place over the four training rides. In fact, performance on ride four (overall) was significantly better than overall performance on ride one ($p < .0001$) as determined by the test for differences in proportions mentioned earlier.

Item five, the probability of failing at least one ride, was found to be 77 per cent. This result is striking because it indicates that 206 of 267 subjects committed errors that would have been potentially fatal in a real ditching situation.

Items six through nine, the observed probabilities of failing only one ride, were not found to be different from one another ($p > .05$). Those subjects failing only one ride made up a total of 30 per cent of the entire sample.

Item ten, the proportion of subjects failing ride four given previous failures on rides one, two and three, was found to be significantly higher than any of the probabilities in items 11, 12, 14 and 15 ($p < .05$). Items 13 and 16 could not be addressed due to their small sample sizes. The result of this analysis is that subjects who failed rides one, two and three were highly likely to fail ride four, while no other combination of failures on rides one through three predicted failure on ride four. Items 17 through 19 provided no further useful results.

The major result of this stage of the analysis is that, based upon overall performance of 267 subjects, learning does occur over the four rides. Considering that each subsequent ride is more difficult than the last, this is even more significant. It must also be noted that fewer than one subject per class was observed to fail two retakes of the checkride, i.e. that virtually all subjects eventually passed the training during their first training session.

B. 9D5 SEAT VERSUS RIDE INTERACTIONS AND THEIR RELATION TO PERFORMANCE

The specific results of this study are presented in a pictorial format so that specific performance statistics can be related to the escape route prescribed for each subject. The number and percentage of subjects who failed each seat-ride combination are listed on the figures described below.

1. 9D5 Rides One and Three

Figure 11 contains performance statistics for rides one and three of the training sequence since the prescribed escape routes were the same (i.e. each subject egressed via the nearest exit).

Ride one simulated a daytime sinking while ride three was conducted with the subjects wearing blacked-out goggles to simulate a nighttime sinking. No differences in performance were noted between subjects seated in the four different crew positions on ride three. Subjects in seat two on ride one failed significantly less often than subjects in seats three or four while no difference was indicated between seats one and two. (All differences were significant at the .01 level.)

It is interesting that seat two on ride one was the least failed, perhaps because seat two is oriented somewhat like the driver's seat of an automobile. There could be some transfer of skills occurring which made it easier for the subjects to operate the hatch release mechanisms, etc.

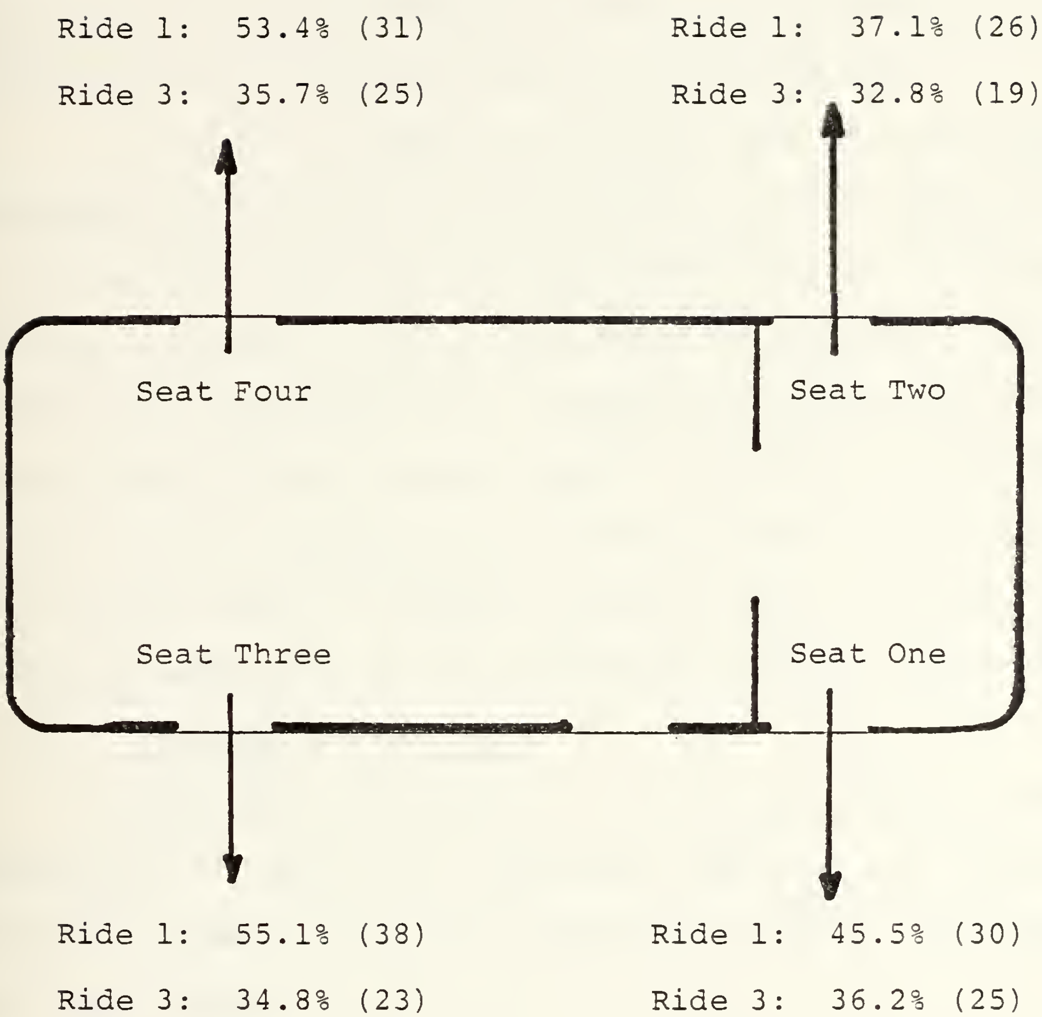

Figure 11. PERCENTAGE OF SUBJECTS FAILING EACH SEAT ON RIDES ONE AND THREE (NUMBER OF FAILURES)

with their left hands and then exit through the left window. In any case, seat two on ride one was easier to escape from when normal vision was allowed. This is somewhat puzzling because on ride three (with no vision) results indicated approximately equal performance over all four seats and at the same level recorded for seat two on ride one.

A constant, underlying failure rate of one-third (approximately) appears to run through all data examined up to this point. This suggests that one-third of all subjects could be expected to fail any particular ride while specific difficulties associated with a particular seat-ride combination add to the failure rates for individual seat positions. It also suggests that learning over the course of the training tends to reduce the error rate in the more difficult seats down to the "baseline" rate of one-third.

2. <u>9D5 Rides Two and Four</u>

Performance statistics for rides two and four are summarized in Figure 12. Arrows are drawn on the figure to describe, schematically, the prescribed escape routes for each seat position.

Ride two, which was accomplished by egressing via the main entry door (without blindfolds) was observed to be most difficult in seat three ($p < .001$). This is easily explained by the requirement for the seat-three occupant to move to the main entry door and operate its simulated hatch release mechanisms before egressing. Most errors in

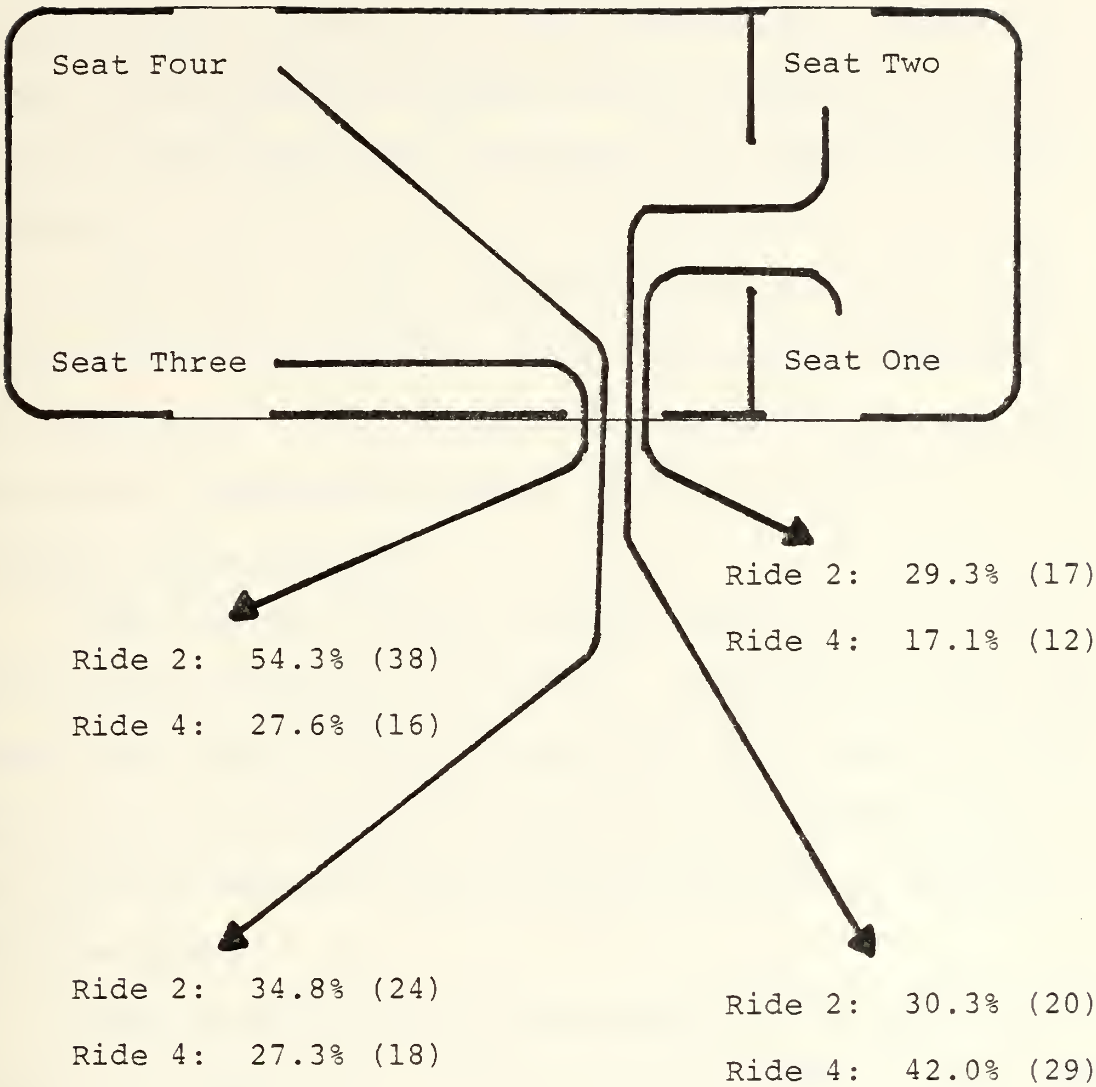

Figure 12. PERCENTAGE OF SUBJECTS FAILING EACH SEAT ON RIDES TWO AND FOUR (NUMBER OF FAILURES)

this seat-ride combination were due to early seat belt release or to failure in operating the hatch release handles. A task analysis (Appendix C) also suggests that the extra motions and procedures required for seat three on ride two add to its difficulty when compared to the other three seat positions.

Ride four, without doubt, provided the most interesting result of this study. Seat two was more difficult than seat one ($p < .01$) in pair-wise comparisons. The task analysis and the specific errors observed on ride four tend to explain these results.

Seat one has the most direct escape route and the easiest task structure on ride four. Although the seat one occupant must find his way to the main entry door, all this really entails is finding one good tactual reference point with the left hand and then swinging around this point to locate the door.

Seats three and four have approximately equal tasks to perform on ride four. While the seat three occupant must locate and operate the main entry door escape handles, the seat four occupant must travel further and locate intermittent tactual reference points to find the main entry door.

Seat two, though only three feet away from seat one, had the highest failure rate noted on rides three or four. In fact, seat two on ride four ranks fifth (only four other rides showed more failures out of 16 possible seat-ride

combinations) in total failure rate even though learning was shown to occur on rides one, two and three (to be discussed in the next section). Specific errors on ride four were attributed directly to disorientation in more than 60 per cent of the failures (i.e. "Wrong Hole," "Pulled Goggles," "Diver Rescue," etc.). Since seat two requires the subjects to make both a right turn when leaving the seat and a left turn to find the door (after being subjected to deceleration forces and being rolled upside-down), vestibular disorientation is highly suspected.

C. PROPORTION OF SUBJECTS SUCCEEDING, BY RIDE, FOR EACH SERVICE GROUP

This section highlights the significant inter-group differences. Figure 13 is a graphical representation of the observed relationships between percentage of success and 9D5 training ride for each group. Table XI is a listing of failure grades for each group on each of the four rides, as well as a listing for the overall distribution of failure grades for each ride.

Examination of Figure 13 illustrates the learning trends over the four rides. As previously noted, the overall learning performance of the total sample of subjects was shown to improve across the four rides. The differences in performance illustrated by analysis of Figure 13 are informative, and in some cases, statistically significant. Aviation Officer Candidates performed better than Navy

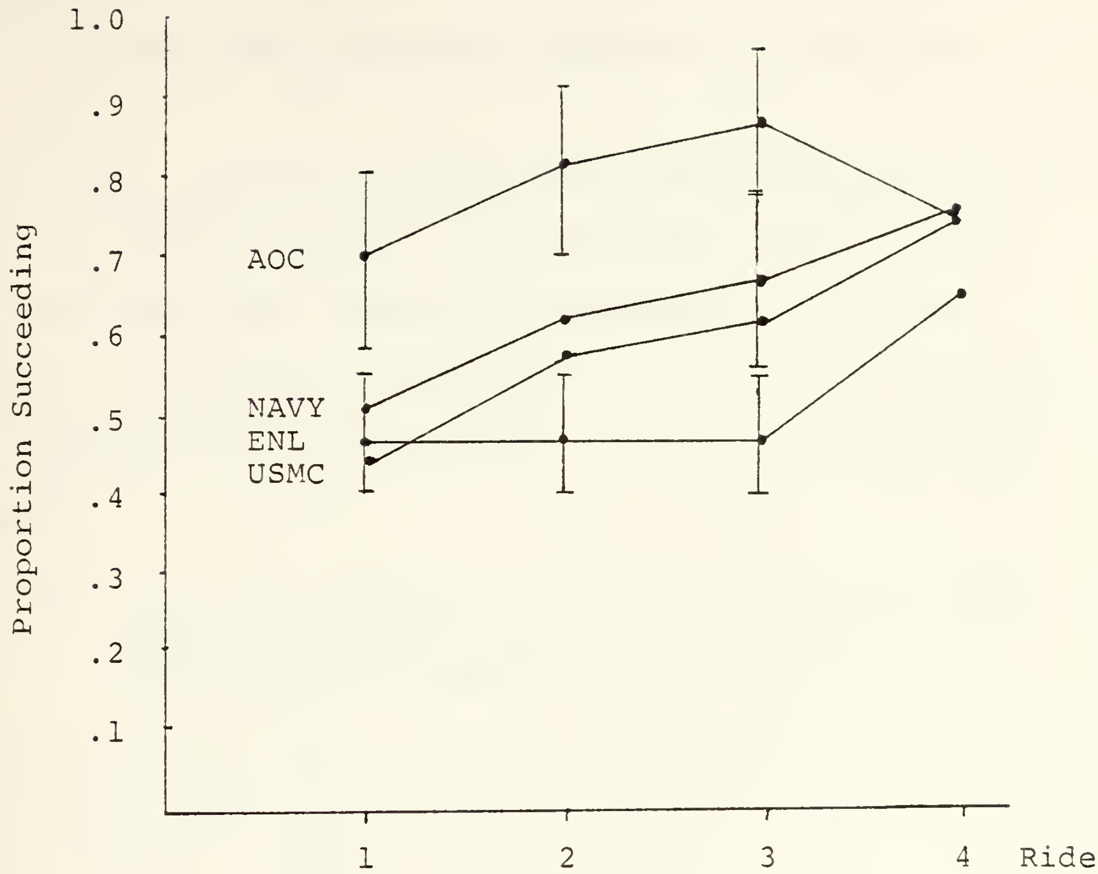

Figure 13. PROPORTION OF SUBJECTS SUCCEEDING ON EACH RIDE, BY SERVICE GROUP (SIGNIFICANT 95% CONFIDENCE INTERVALS ARE DRAWN AROUND SEVEN POINTS TO ILLUSTRATE DIFFERENCES IN PERFORMANCE)

Officers on each of rides one through three ($p < .05$) and better than Enlisted Aircrewman Candidates on ride four ($p < .055$).

The drop in Aviation Officer Candidate performance between rides three and four was unexpected. While errors associated with poor learning of procedures ("Multiple Failures," for example) remained constant, errors associated with disorientation ("Wrong Hole," "Pulled Goggles," etc.) increased.

Table XI. ABSOLUTE FREQUENCIES OF FAILURE CODES FOR EACH RIDE, BY SERVICE GROUP (SEE TABLE VIII FOR DEFINITIONS OF MNEMONIC FAILURE CODES)

Service Group	Ride One	Ride Two	Ride Three	Ride Four
NAVY	ER 20	ER 14	ER 8	ER 2
	NP 6	NP 4	NP 3	NP 0
(n=65)	MF 5	MF 2	MF 9	MF 2
	PA 1	SB 3	SB 2	SB 2
		WH 2		WH 4
				DR 4
				PG 2
USMC	ER 23	ER 15	ER 13	ER 2
	NP 7	NP 6	NP 3	NP 0
(n=76)	MF 12	MF 6	MF 10	MF 2
	PA 1	SB 1	SB 3	SB 3
		WH 2	WH 1	WH 6
		DR 2		DR 2
				PG 3
ENL	ER 17	ER 8	ER 10	ER 8
	NP 7	NP 8	NP 12	NP 0
(n=64)	MF 6	MF 7	MF 6	MF 8
		SB 2	SB 0	SB 3
		WH 4	WH 1	WH 3
		DR 1	DO 1	DO 1
AOC	ER 13	ER 1	ER 3	ER 0
	NP 1	NP 3	NP 1	NP 0
(n=58)	MF 3	MF 3	MF 1	MF 6
	SB 1	SB 3	SB 1	SB 0
		WH 1	WH 1	WH 6
			PG 1	PG 3

Examination of ENL grades shows that Enlisted Aircrewmen Candidates were well behind Aviation Officer Candidates in learning the procedures required for successful completion of the four rides. For example, Enlisted Aircrewman Candidates had a total of 11 failures on ride four which were directly attributable to procedures errors (three "Slide Bar" and eight "Early Release" errors) while Aviation Officer Candidates had none. The "Multiple Failures" classification complicates this analysis because it can occur due to procedural and disorientation errors in combination. However, "Multiple Failures" indicate that the subject was having trouble carrying out the proper sequence of events necessary to complete the ride, therefore "Multiple Failures" are considered to be procedural in nature.

The differences in learning rates, particularly for enlisted personnel as shown in Figure 13, are considered to be the result of a lack of motivation. Aviation Officer Candidates are known to be highly motivated by virtue of their rigorous training schedule, and it is felt that this motivation leads to a higher initial level of performance. The other three service groups, however, do not experience the same arduous training every day as the Aviation Officer Candidates and may, in fact, believe that little is to be lost by failing one or two rides in the 9D5 device so long as ride four is passed. The Aviation Officer Candidate, however, might be required to explain failure to his Marine

Drill Instructor (a painful evolution which could be made worse by push-ups, running, etc.).

D. BIOGRAPHICAL QUESTIONNAIRE RESULTS

The results obtained from the Biographical Questionnaire were largely unexpected and not extremely useful. Nevertheless, the data will be presented briefly.

1. Age Differences Among Subjects

The ages of the subjects, as supplied in the questionnaire, are summarized in Table XII. An analysis of variance (Table XIII) showed the Enlisted Aircrewman Candidates to be younger, on the average, than the other three service groups. This was verified using Tukey's HSD procedure ($p < .05$).

Table XII. AGE STATISTICS FOR THE FOUR SERVICE GROUPS, IN YEARS

Service Group	Mean	Std. Dev.	Min.	Max.	N
NAVY	23.65	2.46	21.0	33.0	51
USMC	23.15	1.28	21.0	28.0	69
ENL	20.39	3.34	18.0	33.0	28
AOC	23.95	1.90	20.0	30.0	54

Table XIII. ANALYSIS OF VARIANCE FOR SUBJECT AGE DATA

Source	D.F.	Sum of Squares	Mean Squares	F	Prob
Between Groups	3	189.20	63.07	13.82	.0000
Within Groups	198	903.71	4.56		
Total	201	1092.91			

It must be noted that the sample sizes for each service group differ greatly from the sample sizes associated with the performance data (mile-swim, cross-country run, etc.) in Chapter III. Only 44 per cent of the ENL group (28 of 64) returned questionnaires. The NAVY group had a return rate of 78 per cent while the remaining two groups each had a questionnaire return rate greater than 90 per cent.

The small number of enlisteds returning questionnaires posed serious problems for the analysis of this data. It was felt that the age data should be fairly accurate, however, since 54 of the 64 enlisteds were in the lower four pay-grades, thereby suggesting an average time in service of about two years and an average age consistent with that observed above.

2. Reported Participation in Water Sports

Approximately two-thirds of all subjects reported participation in water sports on the questionnaire. No differences were noted among the four service groups that could be related to 9D5 performance. In fact, participation in water sports as measured by the questionnaire had no bearing upon 9D5 training scores. This result is consistent with the fact that total numbers of swimming test failures also failed to predict success in the 9D5 device.

3. Near-Drowning

Less than ten subjects reported a previous near-

drowning experience. No analytical results were obtained, but at least one subject who had a near-drowning experience as an adult was observed to fail all four 9D5 training rides and both supplementary checkrides.

E. SUBJECTIVE ANXIETY QUESTIONNAIRE RESULTS

As previously noted, the low return rate for questionnaires lead to unexpected problems in data analysis. The results must therefore be weighed carefully before broad generalizations are made regarding the application of these results, especially when considering the enlisted crewmen.

1. Overall Anxiety Scores

Overall anxiety scores for the four service groups were remarkably consistent, as illustrated in Table XIV. Attempts to use the overall anxiety scores to explain differences in 9D5 performance were not conclusive.

Table XIV. OVERALL SUBJECTIVE ANXIETY SCALE SCORES REPORTED BY SUBJECTS (ON A SCALE FROM "0" TO "100")

Service Group	Mean	Std. Dev.	Min.	Max.	N
NAVY	63.72	21.41	15.0	90.0	43
USMC	56.94	24.70	5.0	100.0	49
ENL	54.29	29.87	5.0	100.0	28
ACC	57.14	20.41	10.0	95.0	49

A one-way analysis of variance did not detect differences among the overall anxiety scores reported by the subjects in the four service groups. It is interesting to note, however, that all four groups reported an average anxiety rating approximately half-way between calm and

panic. This indicates a moderate level of arousal and shows that the training is not perceived as excessively arduous.

2. Ride Sequence Subjective Anxiety Scores

The ride sequence subjective anxiety scores for the four groups are given in Table XV. Insufficient sample size for each of the groups prevented further analysis, but the "Total" category should not be overlooked since it is descriptive of 191 subjects who returned questionnaires.

Table XV. NUMBER AND PERCENTAGE OF SUBJECTS IN EACH SERVICE GROUP REPORTING MAXIMUM ANXIETY AT A GIVEN POINT IN THE 9D5 TRAINING SEQUENCE

Point During Ride		NAVY	USMC	ENL	AOC	TOTAL
Before Boarding Trainer	Number	16	12	3	15	46
	Per cent	31.4	19.7	10.7	28.8	24.1
On Board Trainer, Waiting to Begin Ride	Number	7	4	5	11	27
	Per cent	13.7	7.6	17.9	21.2	14.1
Descending, Sinking and Rolling Over	Number	7	14	3	14	38
	Per cent	13.7	22.7	10.7	26.9	19.9
Counting, Releasing Belt and Finding Exit	Number	14	10	5	7	36
	Per cent	27.5	16.7	17.9	13.5	18.8
Egressing, Surfacing	Number	0	0	1	1	2
	Per cent	0.0	0.0	3.6	1.9	1.0
After Leaving the Pool	Number	7	20	11	4	42
	Per cent	13.7	33.3	39.3	7.7	22.0

It must be explained that items one through 15 of the ride sequence anxiety questionnaire were collapsed into the six categories listed in Table XV. Ryack et al [1979] performed a similar transformation and showed that trained divers experienced their highest levels of anxiety while sinking, inverted, in the helicopter hulk. The "Total"

column in Table XV indicates that 9D5 subjects experienced their highest levels of anxiety while waiting to board the trainer or after leaving the pool (which is analogous to waiting for the next ride in almost all cases). This is a major difference between trained divers and untrained 9D5 subjects and shows that 9D5 subjects experience more anxiety in anticipation of the training than while actually undergoing immersion in the device.

3. Reported Anxiety Over the Course of Four Rides

The relative anxiety scores reported on each of the four training rides were shown to be related to 9D5 performance figures, by service group. Figures 14 through 17 exhibit the relationships found. The 9D5 performance curves for each group are plotted above bar graphs describing the percentage of subjects reporting increasing, decreasing and constant levels of anxiety on each of rides two, three and four.

Note particularly that a smaller percentage of the Aviation Officer Candidates (Figure 17) report increasing anxiety between rides three and four while they show a large drop in performance (percentage passing ride four). The other three service groups (Figures 14, 15 and 16) exhibit increasing performance and constant or increasing percentages of increasing anxiety in anticipation of ride four.

Table XVI illustrates another interesting finding. Subjects who passed ride four did not show a marked trend

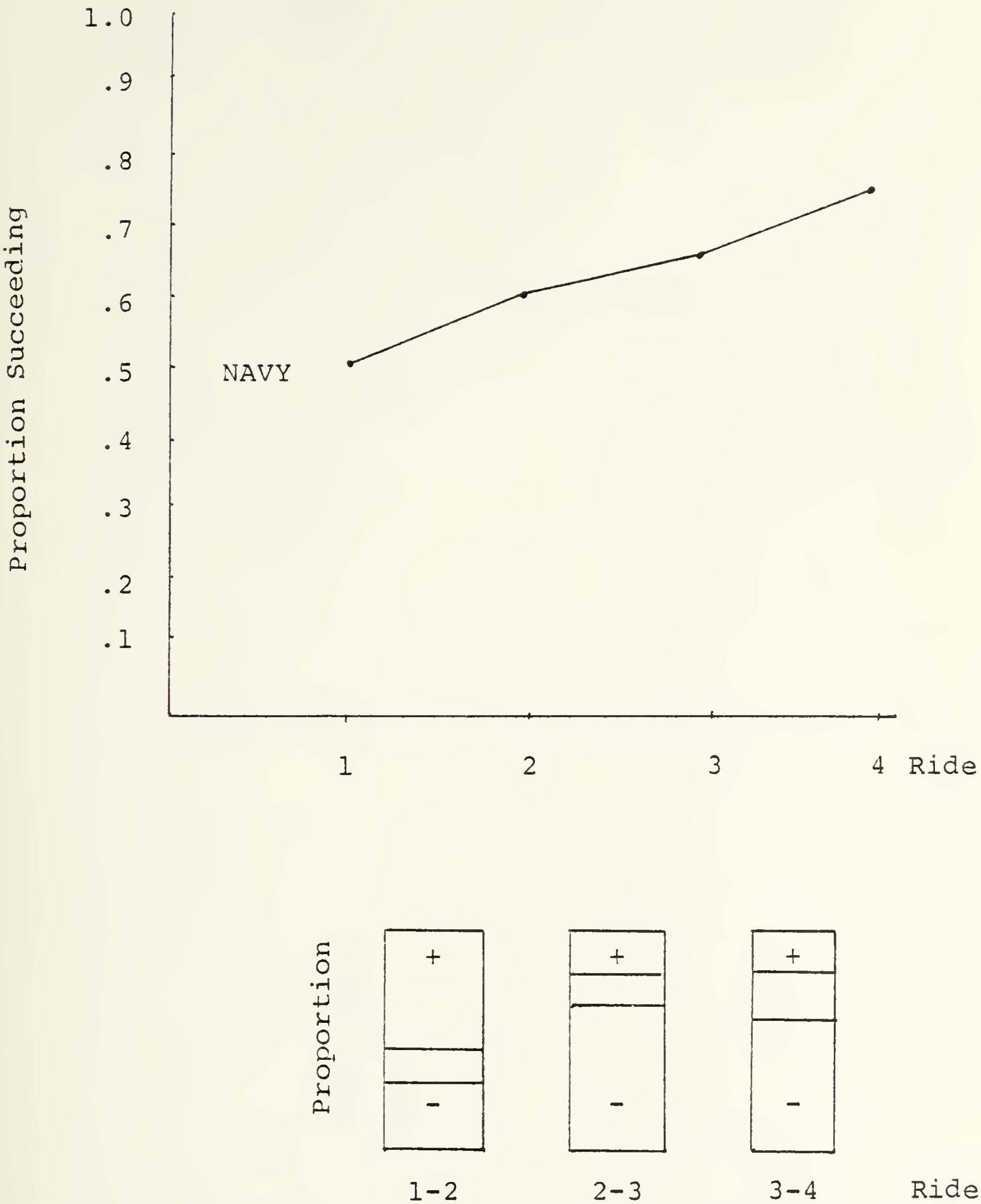

Figure 14. NAVY PERFORMANCE CURVE (ABOVE) AND PROPORTION REPORTING INCREASING (+), DECREASING (-) AND CONSTANT (BLANK) ANXIETY BETWEEN RIDES

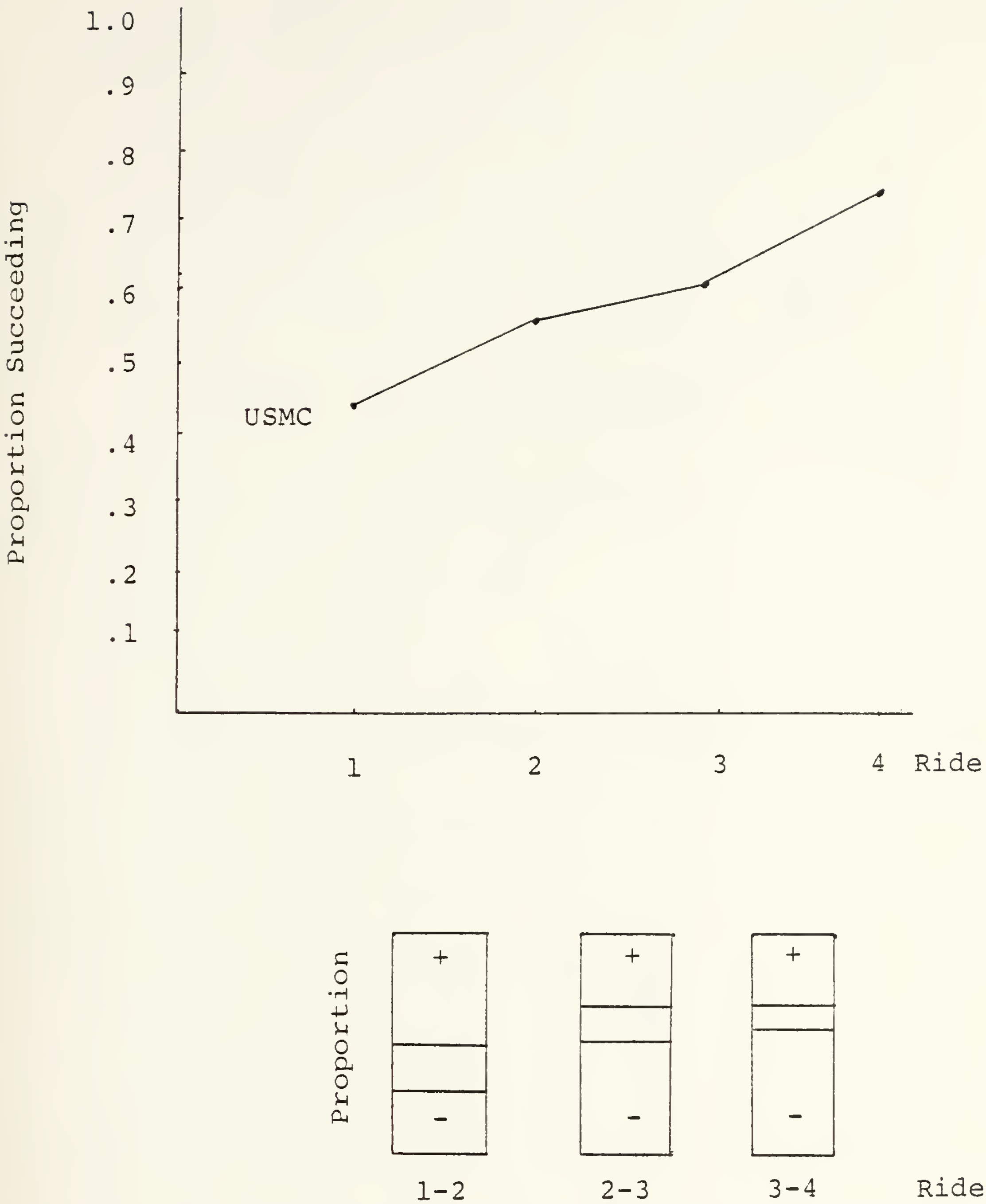

Figure 15. USMC PERFORMANCE CURVE (ABOVE) AND PROPORTION REPORTING INCREASING (+), DECREASING (-) AND CONSTANT (BLANK) ANXIETY BETWEEN RIDES

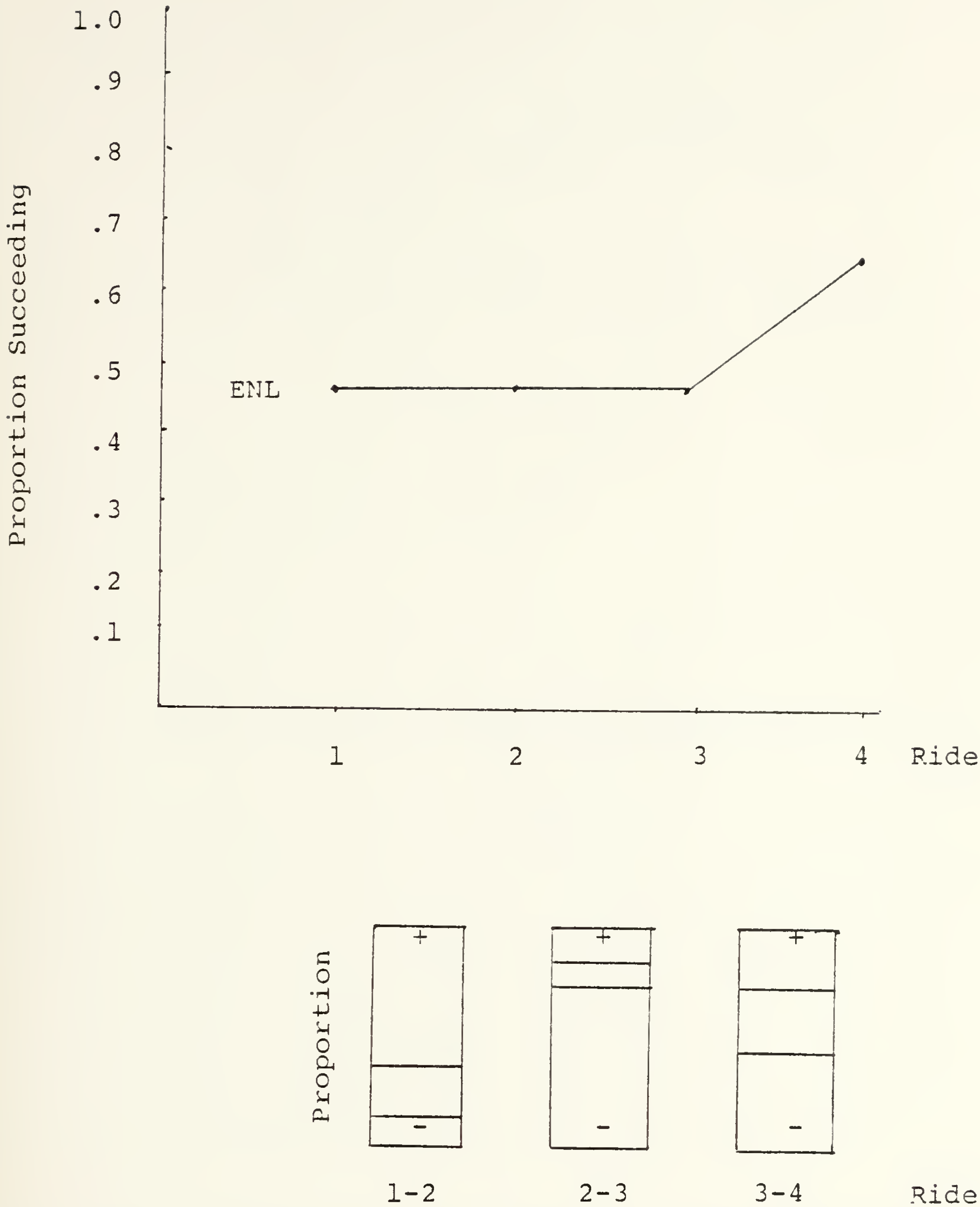

Figure 16. ENL PERFORMANCE CURVE (ABOVE) AND PROPORTION REPORTING INCREASING (+), DECREASING (-) AND CONSTANT(BLANK) ANXIETY BETWEEN RIDES

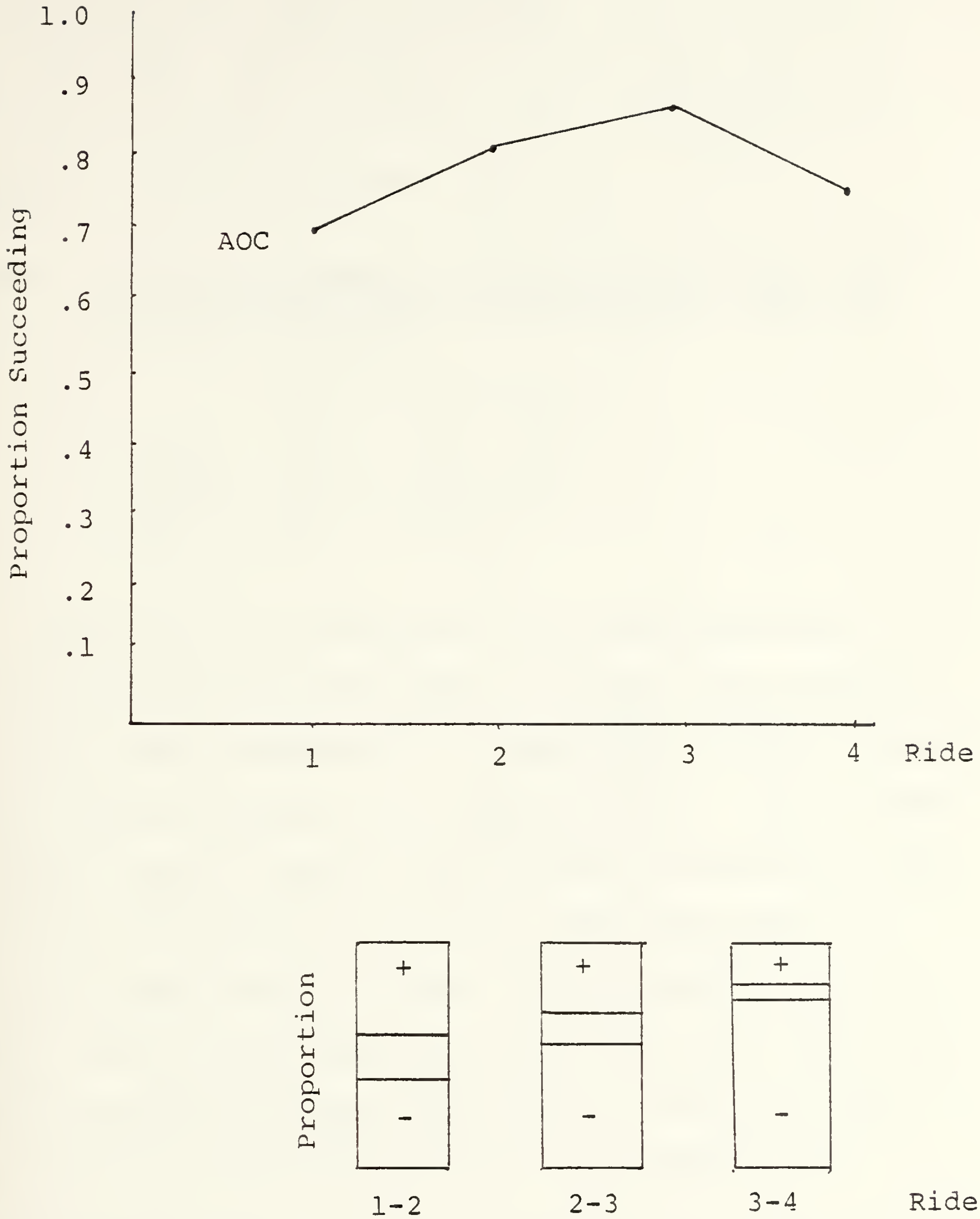

Figure 17. AOC PERFORMANCE CURVE (ABOVE) AND PROPORTION REPORTING INCREASING (+), DECREASING (-) AND CONSTANT (BLANK) ANXIETY BETWEEN RIDES

toward increasing or decreasing anxiety, while individuals who failed ride four reported decreased levels of anxiety in almost every case. For example, in Table XVI it is shown that 40 of 51 subjects who failed ride four also reported a decrease in anxiety between rides three and four.

Table XVI. NUMBER OF SUBJECTS REPORTING DECREASED, STEADY OR INCREASED ANXIETY BETWEEN RIDES THREE AND FOUR BY PERFORMANCE ON RIDE FOUR

	Passed	Failed	Total
Decrease	85	40	125
Steady	18	7	25
Increase	50	4	54
Total	153	51	

Finally, it was discovered that enlisteds who returned questionnaires exhibited an 80 per cent success rate on ride four compared to a 50 per cent success rate for those who did not complete the questionnaire. This finding may explain the low overall return rate for enlisteds since subjects who did poorly in training could have been reluctant to report anxiety levels. More probably, it indicates a lack of motivation and interest among poorer performers as exhibited by the shallowness of the enlisted learning curve on rides one through three (Figure 16).

F. THE RELATIONSHIP OF PHYSICAL FITNESS TO 9D5 PERFORMANCE

The last major result to be presented is that of the predictive value of physical fitness data with respect to 9D5 performance. When it is desirable to predict an outcome

based upon an observed variable, an ordinary least-squares regression model is a most useful tool. A regression model might be formulated, based upon values of the predictive variable and observed outcomes, and then validated with an independent set of data.

In this particular case, it is desirable to construct a prediction model based upon at least one of the measures of physical fitness previously described. If an ordinary least-squares model could be constructed, it would then be possible to take an independent set of data and judge the ability of the model to predict outcomes based upon an examination of actual versus expected outcomes.

A fundamental problem is that 9D5 scores are all pass-fail (or binary) data and cannot, by any means, be assumed to be normally distributed. However, as proposed by Cox [1971], a transformation of the pass-fail data allows the use of the ordinary least-squares model. This transformation and its use in the ordinary least-squares model is described in more detail in Appendix A. For the purposes of this discussion, it is sufficient to state that a model was constructed which related mile-swim times to the "Log-Odds" of Success in the 9D5 device. Log-Odds of Success can easily be converted to P(s), the Probability of Success, to facilitate the interpretation of this model.

The researcher attempted to construct a multiple regression model which could predict success in the 9D5 device as a

function of mile-swim times, cross-country run times and obstacle course times. While these three variables are reasonable predictors of success within some service groups, they are not good predictors across all four service groups. The reason for this failure is that the four service groups each exhibit unique characteristics with regard to physical fitness measures (as was seen in Chapter III). So, for example, obstacle course times might have been good predictors of success in the 9D5 for Marine Corps Officers while obstacle course times had little predictive value when applied to Enlisted Aircrewman Candidates. Since there was not enough data available to construct four different regression models (much less for validation purposes) it was decided to pick the best single predictor across all four service groups and construct a regression model based upon one variable. Mile-swim time (as indicated from the very first pilot studies the researcher conducted in Pensacola) was determined to be the best predictor of success in the 9D5 device. The intuitive appeal of a prediction model based upon mile-swim times also influenced this decision since such a model could be used by Naval Aviation Schools Command personnel to identify students prone to difficulties in the 9D5 device prior to the 9D5 training session.

A Logistic Regression model was formulated based upon mile-swim times and was cross validated by splitting the sample of 267 subjects into an "experimental" and a "control"

group. The two groups were formed by taking every-other subject from each 9D5 training class and assigning them alternately to the experimental and control groups. In this way, the proportion of Navy Officers, Marine Corps Officers, Enlisted Aircrewman Candidates and Aviation Officer candidates was maintained (approximately) in each group.

The regression model itself was constructed using only the "experimental" group and was then run against the "control" group data for cross validation. Figure 18 shows the "control" group data plotted over the regression line determined from the "experimental" model. Only eight points are plotted because these eight points represent the center point (median) of each of the "eighths" of the distribution of mile-swim times observed for the "control" group plotted against the performance of all subjects whose mile-swim time fell within each particular "eighth."

A Chi-square Test was performed comparing the expected proportion of success for the "control" group (predicted by the "experimental" model) with the observed proportion of success for the "control" group. The "control" data was found to fit the regression model quite well (observed $X^2 = 10.12$, $X^2_{\{.95,7\}} = 14.07$). Furthermore, the correlation between the predicted and observed proportions of success for the "control" group was found to be 0.81 ($p < .01$, N pairs = 8). It must be noted that this model was not

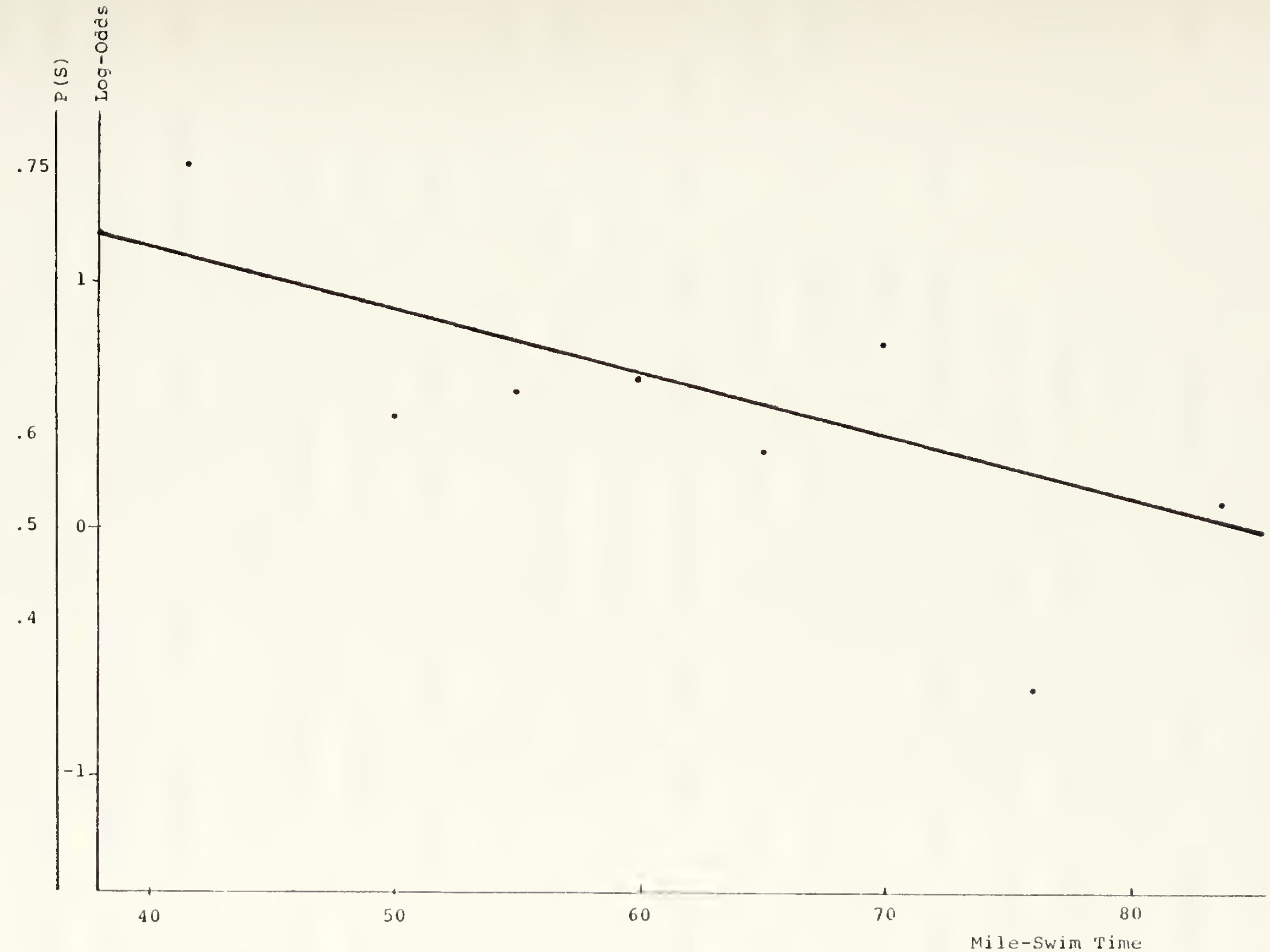

Figure 18. "CONTROL" GROUP DATA POINTS (EIGHTHS OF MILE-SWIM TIME VS. LOG-ODDS OF SUCCESS) PLOTTED OVER "EXPERIMENTAL" REGRESSION MODEL LINE. A PROBABILITY OF SUCCESS SCALE (P(S), NON-LINEAR) IS ALSO SHOWN.

corrected for differences in variability among the "eighths" and so is not strictly correct in the statistical sense. A corrected model using weightings to adjust for differences in variability among the eight intervals gave very similar results (correlation between observed and predicted was 0.71 which is still significant at the .05 level) although the Chi-square Test showed a lack of fit due solely to the contribution of the "eighth" interval containing the highest mile-swim times. This same interval contributed most to the Chi-square statistic of 10.12 noted in the uncorrected model, which leads to the conclusion that the regression model is very good for mile-swim times up to about 80 minutes. An anecdotal explanation for this behavior is that some subjects are "satisfiers" who seek only to complete the mile-swim test in the allotted time and who make no attempt to learn the 9D5 procedures until ride four. This would associate high mile-swim times with subjects showing low motivation. In any case, for groups of subjects having similar mile-swim times, we are able to predict the group's overall probability of success (percentage of successes out of all rides experienced by members of the time interval group) reasonably well. For groups of subjects having high mile-swim times, we are less able to predict performance and, in fact, 9D5 performance seems to be almost random (with an approximate 50 per cent success rate).

Due to all of the data manipulations required in for-

mulating this model (grouping subjects by mile-swim time, using all four 9D5 rides for computation of the Log-Odds of Success, etc.) it is not advisable to predict performance for an individual using this model. However, based upon earlier attempts to predict 9D5 performance, this model is a resounding success. Since a link between 9D5 performance and mile-swim time performance has been established, this relationship could eventually be used to justify 9D5 training requirements for poorer swimmers (i.e. poorer swimmers as measured by mile-swim time do poorly in the 9D5, so poorer swimmers should get 9D5 training before getting into a situation where a real ditching is a possibility). On the other hand, poor swimming ability could be used to screen out personnel who have a greater potential for difficulties in an egress situation and simply restrict them from flying over the water in helicopters.

Finally, by re-examining the raw data used to construct the regression model, it was discovered that poorer swimmers actually got less benefit from the first four training rides than did the better swimmers. For example, for "experimental" subjects who took between 74 and 79 minutes to swim a mile, the observed proportions of failure on rides one through four were 8/11, 8/11, 7/11 and 6/11. In contrast, the "experimental" subjects who took between 47 and 52 minutes to swim a mile had failure rates of 8/13, 6/13, 2/13 and 4/13 over the four rides. This result suggests that

better swimmers are able to learn the 9D5 procedures faster than the poorer swimmers do. It also makes a strong case for continuing the other swimming and water survival training classes that are prerequisites for 9D5 training. There is the suggestion that 9D5 training would simply be wasted on personnel who are not proficient in the water.

In spite of the foregoing discussion, the reader should not conclude that swimming or physical fitness programs would enhance survival in a 9D5-like egress scenario. While some relationship does exist, no cause-and-effect has been established. Furthermore, a slow mile-swim time may be due to the fact that the subject is simply not in a hurry or has no cause to compete with his peers. There are always those individuals who simply "satisfy" the mile-swim time requirement of 90 minutes and then subsequently perform perfectly in the 9D5.

In conclusion, Figure 19 is a histogram plot of the observed proportion of successes in the 9D5 device versus mile-swim time. This figure presents data for the entire 267 subject population.

G. EXAMINATION OF HYPOTHESES

The hypotheses listed earlier will now be discussed in light of the previous analytical results.

1. Physical Fitness is Related to 9D5 Performance

This hypothesis is strongly supported by the results

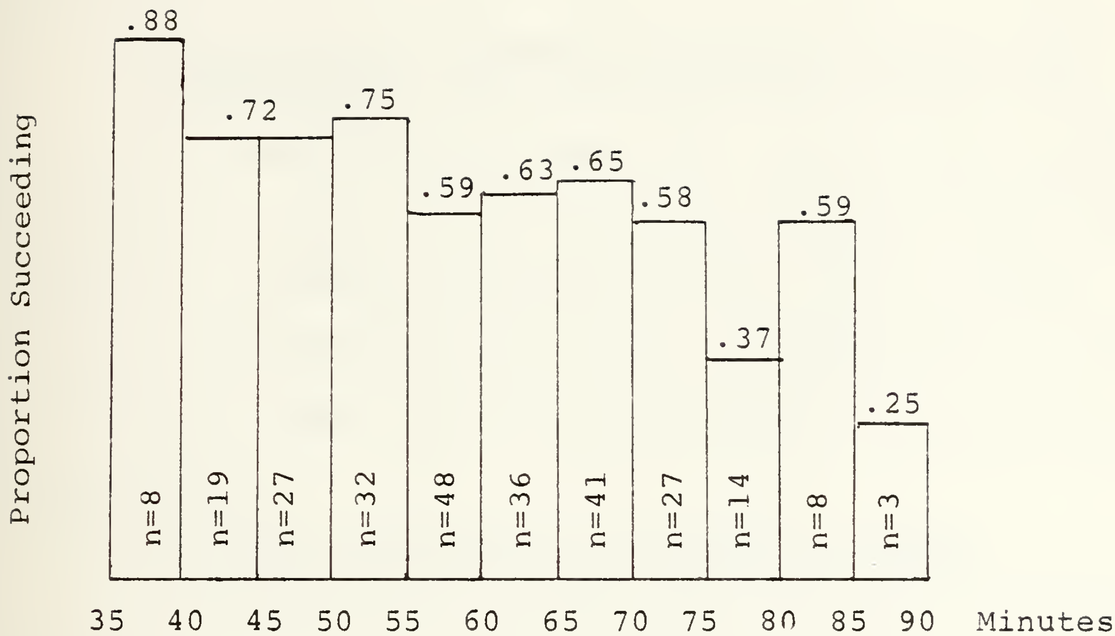

Figure 19. PROPORTION OF SUCCESS BY FIVE-MINUTE MILE-SWIM TIME INTERVALS

of the Logistic Regression Model analysis. As noted, mile-swim times were found to be generally predictive of overall success in the 9D5 device, with better swimmers giving a better performance. This result is analogous to the findings of the Army Airborne training study and the Underwater Demolition Team training study examined earlier. Although the exact mechanism is not fully explained, fitness does have an effect upon the ability of subjects to perform the egress task.

2. <u>Swimming Test Grades May Be Used to Predict 9D5 Performance</u>

Although mile-swim times were found to be related to 9D5 success, individual pass-fail swimming tests were not indicative of possible success or failure in the device. In fact, several different approaches to the analysis of pass-fail swimming test data failed to turn up any predictive relationships.

3. <u>Poor 9D5 Performance is Related to Anxiety</u>

This hypothesis was not supported by the examination of anxiety trends across the four training rides. The surprising result, however, was that poor performance was linked to decreasing reported anxiety levels. Either the subjects who performed poorly were over-confident and reported lowered levels of anxiety, or possibly, the lower anxiety levels among poor performers could be related to a lack of motivation.

4. Seat Position Influences 9D5 Performance

This hypothesis was very strongly supported by the analysis of seat versus ride failure data. Marked differences in performance were noted which can apparently be explained by the difficulty of the task associated with each seat on particular rides. Most notably, seat two on ride four was failed by 42 per cent of the subjects riding in that seat while the occupants of seat one, only three feet away, showed a 17.1 per cent failure rate (on four).

5. The 9D5 Device Produces Disorientation

This hypothesis, related to the one above, is also strongly supported. The literature examined supports this finding on the basis of previous studies and the 9D5 operating parameters alone. Adding a blindfold merely aggravated an already disorienting situation.

The lack of visual clues, combined with vestibular inputs caused by the 9D5 operating sequence and the multiple changes of direction required to escape from seat two on ride four caused the observed decrement in performance. Furthermore, unfamiliarity with underwater maneuvering by feel alone could only have contributed to the confusion.

6. Biographical Information Can Be Used to Predict 9D5 Performance

Based upon the reported participation in water sports, no support is found for this hypothesis. Therefore, success in the 9D5 device is not directly related to par-

ticipation in any other kind of stressful water activity.

7. <u>Near Drowning Experiences Are Correlated with Difficulty in the 9D5</u>

While the trend toward panic in some subjects seems related to previous near-drowning experiences, the majority of subjects reporting a near-drowning did not have significant difficulties. Overall, the number of persons reporting near-drowning was too small for statistical analysis.

H. ADDITIONAL FINDINGS

As briefly noted above, physical fitness (as measured by mile-swim times) is related to performance in that very fast swimmers show little evidence of difficulty in the 9D5 device. This result is of particular interest since a similar study (Army Airborne training) showed that good performance was related to fast times observed on a two-mile run test.

The apparent heirarchy of performance across Officer Candidate, Officer and Enlisted ranks (i.e. that Officer Candidates do the best while Enlisteds do the worst) was also noted in the Army Airborne Training study. That study concluded that the differences in performance were related to motivation, and a similar statement could be made about the 9D5 training subjects. At the very least, differences in motivation would help to explain the low questionnaire return rate shown by Enlisted subjects. Aviation Officer Candidates are known to be highly motivated, so this may

help to explain their initial overall superior performance in the 9D5.

The most interesting result in relation to the previous study of underwater egress performance using UDT members as subjects is that, while UDT members reported decreasing levels of anxiety across their entire training period, two thirds of the subjects in the present study reported higher anxiety on ride four than on ride one. The UDT members also reported that their highest levels of anxiety occurred while sinking upside-down in the H-3 hulk while 9D5 subjects showed anticipatory anxiety in contrast to other portions of the training ride.

V. IMPLICATIONS

A. IMPLICATIONS FOR 9D5 TRAINING

The results of this study have several areas of potential application for personnel involved in training students with the 9D5 device.

1. Seat Versus Ride Differences

The matter of unequal difficulty for the various seats on rides one, two and four must be addressed. While ride one shows differences in performance among seats, this is probably not critical since it is the first exposure to the egress problem and, from a task standpoint, is potentially the easiest ride. While ride two demonstrates the ability of subjects to locate the main entry door equally well from all seats (i.e. very little disorientation occurs) it also indicates that the man responsible for "opening" the main entry door (seat 3) experiences many more "procedures" errors than the other three subjects. Ride three, of course, is no problem since all seats were shown to be equally difficult. Ride four accentuates the potential for disorientation in subjects and also indicates that seat two is unusually difficult. (Figure 20 shows the effects of "partialling-out" disorientation errors on ride four as compared to the performance curves shown in Figure 13.) If it is really useful to train subjects in the 9D5 device,

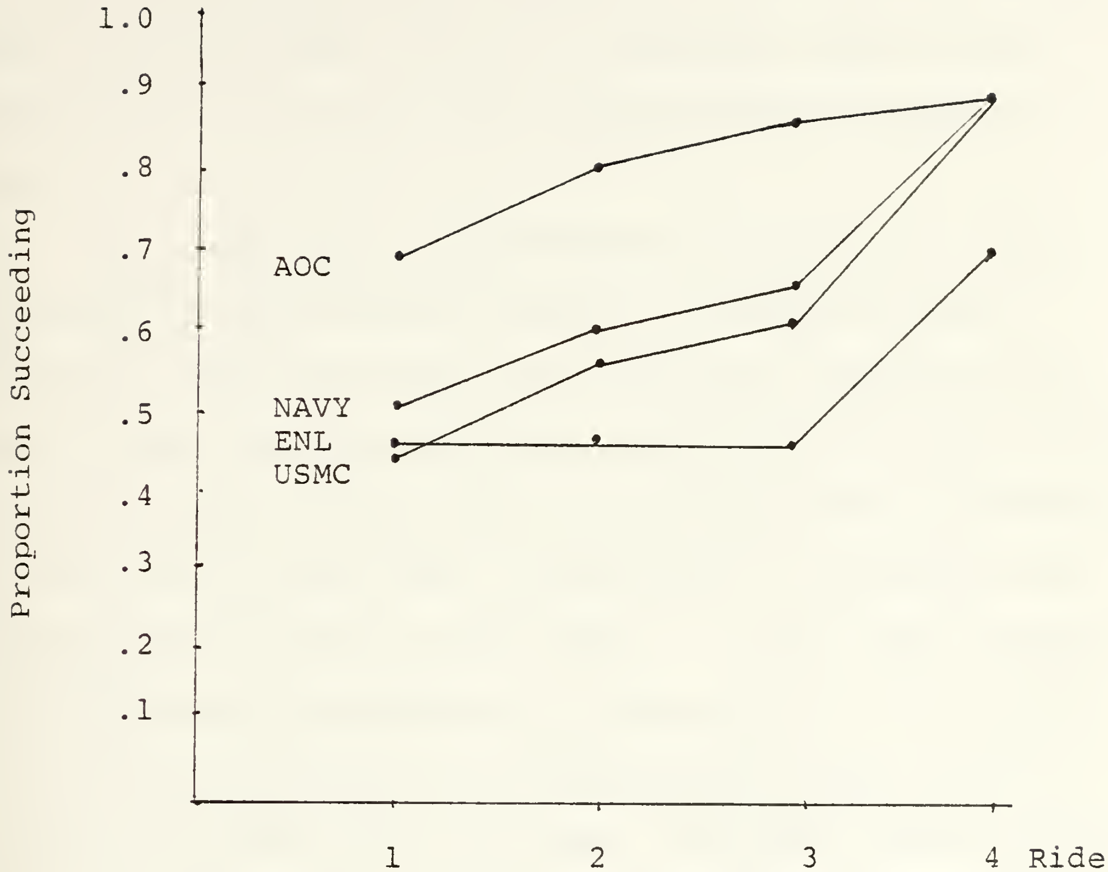

Figure 20. PROPORTION OF SUBJECTS SUCCEEDING ON RIDES ONE, TWO AND THREE, AND PROPORTION OF SUBJECTS WHO WOULD SUCCEED ON RIDE FOUR IF DISORIENTATION WERE ELIMINATED

the subjects should all receive a checkride of equal difficulty. An alternate seat rotation or egress path scheme seems to be indicated, however, this would require major modification of training aids and procedures currently in use.

The difficulties experienced in seat two on ride four might be ameliorated through an alternate egress technique. Since at least two directional changes are required under present procedures, positive orientation within the device must be maintained. It is suggested that subjects be instructed to get "down" on the deck of the device immediately after leaving their seats. In this way, the subject eliminates one dimension of free motion (the relative vertical) and can counter the tendency to rotate too far to the right when leaving the seat. By being "down" on the deck, the subject can assume a face-down position which may permit him to find the tactual reference points necessary for a left turn toward the main entry door. The same technique would be useful in a fleet aircraft which may have a door on either side of the fuselage. The technique, in short, would be one of crawling on hands and knees rather than swimming (and would of course be dependent upon finding tactual clues and reference points that would permit continued contact with the deck).

2. Motivation of Subjects

The flat learning curve over rides one, two and

three observed for Enlisted subjects must be addressed. Enlisted personnel should be capable of learning the 9D5 egress procedures just as well as anyone else, and, in fact, may have more reason to be concerned with egress since they normally ride in the main cabin and may not be seated next to an exit. It is suggested that more "dry" training (walking through egress routes in the trainer, etc.) be applied for Enlisted subjects since they are benefiting less from the training overall as evidenced by their lower and slower learning pattern (Figure 13). Utilization of a mock-up device (a "Kiwi" in naval terms) might decrease the number of checkride failures. Furthermore, the value of rehearsal in learning must not be forgotten [Welford, 1976].

Alternately (and more realistically, from a practical view), some penalty could be exacted for poor performance that indicated a lack of effort to learn the procedures. For example, if two of the first three rides were failed, an extra "practice" ride could be required whether or not ride four was failed. This sort of criterion might induce subjects to pay more attention to the briefing, the procedures, and their performances on rides one, two and three. Anecdotally, some subjects were heard to remark that "only ride four matters" and so concentrated only on ride four.

A final suggestion is that a written test be given before 9D5 training begins in order to reinforce learning and to test knowledge of procedures. Such an exercise

might reduce the failure rate due to procedural errors. Classroom instruction or a programmed text might also be administered during the morning or afternoon before the 9D5 training is scheduled.

If a programmed text were developed, it could be distributed to fleet squadrons as a basis for safety lectures, etc. and could serve as a model for locally prepared texts covering egress procedures in specific aircraft. This would benefit everyone who flies in multi-place aircraft and could actually be stowed aboard some aircraft for the benefit of troops, passengers, etc.

B. EGRESS AID DESIGN CRITERIA

There are two strong indications which can be addressed to design criteria. The first is that lack of vision contributes overwhelmingly to disorientation. The second is that even simple sequential procedures are easily forgotten under the stress of breath deprivation [Egstrom and Bachrach, 1971]. It is therefore suggested that primary efforts in the field of egress aid development be directed toward visual egress path identification.

The results of this study indicate that one-third of all subjects can be expected to have difficulty with procedures or disorientation on any ride. Considering that 9D5 training takes place under near ideal conditions (pre-brief, practice, no surprises, etc.) it must be acknowledged that

a sudden emergency ditching with untrained subjects on board would probably be disastrous (and usually has been). Furthermore, even if training were universal, visual aids would provide the most assistance to ditching victims by eliminating the possibility for getting lost inside the aircraft.

Emergency breathing devices would be desirable in addition to visual egress aid systems, however, a basic course in SCUBA diving would be needed to ensure proper use of the device and prevent air embolism in untrained subjects.

In summary, the study of 9D5 subjects shows that the primary difficulties in egress are disorientation (caused by early seat belt release, in-rushing water or darkness) and procedural errors (inability to operate door handles, seat belt buckles, etc.). By taking the man out of the system and making as many functions as possible automatic (such as automatic hatch separation on impact) and then allowing him to capitalize on his greatest natural perceptual abilities (i.e. vision), survival would be enhanced.

C. AREAS FOR FURTHER RESEARCH

1. Testing Considerations for Egress Devices

The proposals outlined above should be tested thoroughly before implementation on a wide scale basis. The limited funds available for research must be applied where they will do the most good, so it is recommended that proposals be tested on non-diver personnel. It has been shown

that trained divers perform differently from 9D5 subjects, so that testing any device using only trained divers would be a grievous mistake.

Since flight students have a vested interest in egress training, it is suggested that volunteers for testing be solicited from flight students who are waiting to report to Pensacola.

Once the safety of the egress aid equipment is certified using trained divers, the student volunteers could be tested in order to judge the benefits gained with respect to uninitiated personnel. Safety could be maintained even in total darkness or "red-light" conditions by testing only one subject at a time, use of available night vision equipment by safety observers, and conducting the tests in a heavily curtained building so that daylight would be immediately available in the event of a power failure. In fact, if scheduled properly to prevent interference with normal training requirements, this type of study could be carried out using one of the existing 9D5 devices.

2. Prediction of Success in Flight Training

Flight training is a stressful, demanding activity which is not designed to be easy for the students. Many students fail to complete flight training every year due to poor performance and poor motivation. It is possible that training in the 9D5 device could be indicative of success in flight training and, if so, performance grades for 9D5

students might be used to identify those students who are unlikely to complete flight training.

A better application for relating 9D5 grades to success in flight training would be to identify those students who are predisposed to anxiety under stress. Then, those students could be counselled before their flight training began in hopes of preventing their eventual attrition due to voluntary disenrollment or stress related problems such as air-sickness, etc.

VI. SUMMARY

This study examined the performance of 267 military personnel undergoing the water survival syllabus at Naval Aviation Schools Command, Naval Air Station Pensacola, Florida in preparation for aviation training. The study was centered around the 9D5 Multi-Place Universal Underwater Egress Trainer, a device designed to train aviation personnel to escape from a sinking aircraft.

Objective data elements describing performance on a mile-swim test, a cross-country run, an obstacle course and several other swimming tests were examined in an effort to identify those data elements which were predictive of performance in the 9D5 device.

Subjective data was gathered using a questionnaire administered to the subjects following training in the 9D5 device. The subjects rated their levels of perceived anxiety on three different scales describing various events during the course of the training.

Several important results were obtained from the study. First, mile-swim times were found to be predictive of overall performance for the group of 267 subjects examined, i.e. those subjects who swam a mile in the shortest times were the most successful in the training. The poorer swimmers showed far less success and far less evidence of learning

over the course of the training. Overall, better physical fitness as measured on the mile-swim task was associated with better performance and faster rates of learning.

The reported anxiety levels experienced by the subjects in training were markedly different from those reported by trained divers in an earlier study. While Navy divers reported their greatest anxiety occurred while underwater, the flight students reported their greatest anxiety occurred while waiting to board the device or while waiting for the next ride. Also, the divers reported a decrease in anxiety over the course of training while two-thirds of the flight students reported an increase in anxiety from rides one to four.

Finally, differences in performance among sub-groups were noted and explained primarily due to motivation and the service group of the subjects. Officer Candidates performed best, followed by commissioned officers (Navy and Marine Corps) and enlisted personnel.

Primary causes of failure in the device were procedural errors attributed to shallow learning curves and disorientation caused by being blindfolded to simulate night conditions.

Major areas for application of the study are in the realm of visual escape hatch identification, automatic activation of hatch releases and egress aid devices, and improved training methods for poorly motivated personnel.

APPENDIX A

The Logistic Regression Model

The Logistic Regression Model in Chapter IV is of the form

$$\lambda_i = \alpha + x_i\beta$$

and was constructed using an ordinary least-squares scheme where the x_i were the mid-points (median) of the mile-swim time intervals described by the "eighths" of the mile-swim time frequency distribution. The observed λ_i were computed as

$$\lambda_i = \ln \left(\frac{\theta_i}{1 - \theta_i} \right)$$

where θ_i was the observed proportion of success for all subjects whose mile-swim times fell in interval i. For example, if 20 subjects' mile-swim times fell into a particular interval i, θ_i was computed as

$$\theta_i = \frac{\text{Total Successful Rides}}{\text{80 Total Rides Taken}} .$$

The (x_i, λ_i) pairs were then entered into a "canned" ordinary least-squares regression program with the following results:

α (intercept term) = 2.22

β (slope term) = -0.0268

ρ (correlation) = -0.8133

As mentioned in Chapter IV, a "weighted" model was also constructed in which the λ_i terms were multiplied by a factor w_j computed as

$$w_j = \sqrt{\frac{N_{successful} \times (N_{group} - N_{successful})}{N_{group}}} \quad .$$

The results of these two models are outlined in Chapter IV as they were applied to the analysis of the 9D5 training grade versus mile-swim time data.

APPENDIX B

The 9D5 Questionnaire

Samples of the four pages of the 9D5 Questionnaire are presented below in the order administered to the subjects.

PRIVACY ACT STATEMENT

This statement is provided in compliance with the provisions of 44 USC, Section 3101 5 USC, Section 301, which require that all federal agencies must inform individuals who are requested to furnish information about themselves (in this case, name, SSN, age and the described test date) as to certain facts concerning the information requested.

All of the collected data and information requested will be used exclusively for research purposes. Disclosure of this information is voluntary. Under no circumstances will the information be released or divulged to anyone outside the Department of Defense without your express written authorization. Reports describing the results of the study will not make any form of direct or indirect identifications of specific individuals participating in the studies.

I hereby authorize the use of the requested data and information for the stated purposes.

______________________ ______________________________

Date Signature of Volunteer

VOLUNTEER CONSENT FORM

You have been requested to serve as a volunteer subject for the purpose of acquiring data which will serve in the development of underwater egress systems and training devices for aircraft.

Your participation requires your consent to perform certain written tasks and to complete questionnaires related to the 9D5 underwater egress training device. These tasks and questionnaires will be administered before and after your 9D5 training session and will not interfere with your performance during the training session.

You may ask any questions you wish related to the study and complete answers will be given. If you agree to participate in the study, signify your consent by signing immediately below. You may withdraw from the study at any time without prejudice to yourself. Completion of the attached forms is the only action required on your part.

______________________ _____ ______________________________

Name of Volunteer (Print) Age Signature of Volunteer

______________________ ______________________________

Witnessed by Questionnaires Administered by

905 QUESTIONNAIRE

The 15 items listed immediately below describe the sequence of events you experienced during your 905 training. Read over the 15 items and decide which one was the most anxiety-producing event for you. Circle the number 10 on the scale to the right of your most anxiety-producing event. Then, rate the other 14 items according to how you felt during each event. For example if you experienced as much anxiety as in the event you chose above, circle the number 10. If you felt no anxiety at all, circle the number 0. You may use each number as often as you like.

		Perfect calm	Your greatest level of anxiety
1.	Before the training began ----------------	0 1 2 3 4 5 6 7 8 9	10
2.	Waiting to board the trainer -------------	0 1 2 3 4 5 6 7 8 9	10
3.	Boarding the trainer ---------------------	0 1 2 3 4 5 6 7 8 9	10
4.	On board waiting for descent -------------	0 1 2 3 4 5 6 7 8 9	10
5.	While descending -------------------------	0 1 2 3 4 5 6 7 8 9	10
6.	While sinking ----------------------------	0 1 2 3 4 5 6 7 8 9	10
7.	While rolling over -----------------------	0 1 2 3 4 5 6 7 8 9	10
8.	While counting 5 to 8 seconds ------------	0 1 2 3 4 5 6 7 8 9	10
9.	While releasing the seat belt ------------	0 1 2 3 4 5 6 7 8 9	10
10.	While finding the exit -------------------	0 1 2 3 4 5 5 7 8 9	10
11.	While pulling through the exit -----------	0 1 2 3 4 5 6 7 8 9	10
12.	While swimming to the surface ------------	0 1 2 3 4 5 6 7 8 9	10
13.	Reaching the surface ---------------------	0 1 2 3 4 5 6 7 8 9	10
14.	Waiting for the next ride ----------------	0 1 2 3 4 5 6 7 8 9	10
15.	Now --------------------------------------	0 1 2 3 4 5 6 7 8 9	10

The four 905 rides are briefly described below. Using the same scale you used for items 1 through 15, mark each ride to indicate the highest level of anxiety you felt during each ride. You should have at least one grade of 10 on one of the rides since you marked at least one "10" above. For example, if you experienced your greatest anxiety on ride 2, then ride 2 should get a grade of 10. Rate the other 3 rides on the scale of 0 to 10 as you did above. You may use the same number as often as you like.

	Perfect Calm	Your greatest level of anxiety
Ride one (window exit) -------------------	0 1 2 3 4 5 6 7 8 9	10
Ride two (door exit) ---------------------	0 1 2 3 4 5 6 7 8 9	10
Ride three (window exit wearing goggles) -	0 1 2 3 4 5 6 7 8 9	10
Ride four (door exit wearing goggles) ----	0 1 2 3 4 5 6 7 8 9	10

NAME________________________ SSN_____-____-_______ Date_______1980

9D5 QUESTIONNAIRE

NAME________________________________ SSN______________________ Date ________1980

Please place an "X" beside all of the activities listed below that you have actually pursued for a period of six months or longer.

___Certified scuba diver	___Primitive camping
___Salt-water skin diving	___Boy Scouts/Girl Scouts
___Water skiing	___Cross country or marathon running
___Red Cross Senior Life-saver	___Organized competitive swimming
___Sky diving or parachuting	___Part-time jobs during high school
___Pilot training	___College
___Competitive automobile racing	___Church sponsored yough groups
___High school varsity sports	___Cave exploration (spelunking)

If you have ever been involved in a true life-threatening situation, please describe it

briefly:____

____

____

What is your present age? _____

In what town or city and state did you live for the longest time as a child?

____

905 QUESTIONNAIRE

Disregard the scales used earlier. On the scale below, circle the number which you feel best describes the greatest level of anxiety you experienced at any time during your 905 training. On this scale, 0 (ZERO) indicates a state of complete calm and relaxation. 100 (ONE-HUNDRED) indicates a state of extreme anxiety (panic). For example, if you feel that your greatest level of anxiety during the 905 training was near-panic, you should mark a number close to 100. If you felt no more anxiety than you would feel while relaxed and comfortable in your own home, you should mark a number close to 0. You should not make more than one mark on the scale.

Complete calm ______________________________ Extreme anxiety

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

NAME ______________________________

APPENDIX C

Task Analysis

Trainer	Time	Subject
1. begins descent	0 sec.	1. waits for impact, maintains tactual references
2. impacts water	10 sec.	2. actuates window handle and slide bar
3. sinks, rolls		3. a. reestablishes tactual reference points b. begins breath holding when immersed c. begins counting 5-8 seconds (waits for water flow to stop)
4. stops when fully immersed	17 sec.	4. releases seat belt
		5. grasps window frame
		6. pulls out of device with arms
		7. swims to surface
		(8.) removes goggles if applicable
5. retracts	60 sec. (max.)	9. leaves pool for debrief

Figure C1. TASK ANALYSIS FOR WINDOW EGRESS (RIDES ONE AND THREE), APPLICABLE TO ALL FOUR SEATS IN THE 9D5

	Trainer	Time		Subject
1.	begins descent	0 sec.	1.	waits for impact, maintains tactual reference
2.	impacts water	10 sec.	2.	actuates window handle and slide bar
3.	sinks, rolls		3.	a. maintains tactual reference points b. begins breath holding when immersed c. begins counting 5-8 seconds (waits for water flow to stop)
4.	stops when fully immersed	17 sec.	4.	releases seat belt
			5.	turns left out of seat
			6.	moves through tunnel
			7.	continues "left" to door
			8.	grasps door frame
			9.	pulls out with arms
			10.	swims to surface
			(11.)	removes goggles if applicable
5.	retracts	60 sec. (max.)	12.	leaves pool

Figure C2. TASK ANALYSIS FOR MAIN ENTRY DOOR EGRESS (ITEMS ONE THROUGH FOUR) AND, IN PARTICULAR, FOR SEAT ONE EGRESS ON RIDES TWO AND FOUR (ITEMS FIVE THROUGH TWELVE)

	Trainer (continued)			Subject (continued)
			5.	turns right out of seat
			6.	moves through tunnel
			7.	turns left toward door
			8.	grasps door frame
			9.	pulls out with arms
			10.	swims to surface
			(11.)	removes goggles if applicable
5.	retracts	60 sec. (max.)	12.	leaves pool

Figure C3. TASK ANALYSIS (CONTINUED FROM ITEMS ONE THROUGH FOUR, FIGURE C2) FOR SEAT TWO MAIN ENTRY DOOR EGRESS, RIDES TWO AND FOUR

Trainer (continued)			Subject (continued)
		5.	moves toward door
		6.	locates door handle and actuates
		7.	locates slide bar and actuates
		8.	grasps door frame
		9.	pulls out with arms
		10.	swims to surface
		(11.)	removes goggles if applicable
5. retracts	60 sec. (max.)	12.	leaves pool

Figure C4. TASK ANALYSIS (CONTINUED FROM ITEMS ONE THROUGH FOUR, FIGURE C2) FOR SEAT THREE MAIN ENTRY DOOR EGRESS, RIDES TWO AND FOUR

Trainer (continued)			Subject (continued)
		5.	moves toward door
		6.	locates door
		7.	grasps door frame
		8.	pulls out with arms
		9.	swims to surface
		(10.)	removes goggles if applicable
5. retracts	60 sec. (max.)	11.	leaves pool

Figure C5. TASK ANALYSIS (CONTINUED FROM ITEMS ONE THROUGH FOUR, FIGURE C2) FOR SEAT FOUR MAIN ENTRY DOOR EGRESS, RIDES TWO AND FOUR

APPENDIX D

Data Availability

Much of the data used in this study was furnished by individual subjects and is protected by the provisions of the Privacy Act.

Requests for this data from authorized users within the Department of Defense should be forwarded to:

CDR William F. Moroney, MSC, USN
Code 55 MP
Naval Postgraduate School
Monterey, Ca. 93940

All requests for access to this data should be forwarded no later than 1 April, 1982.

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