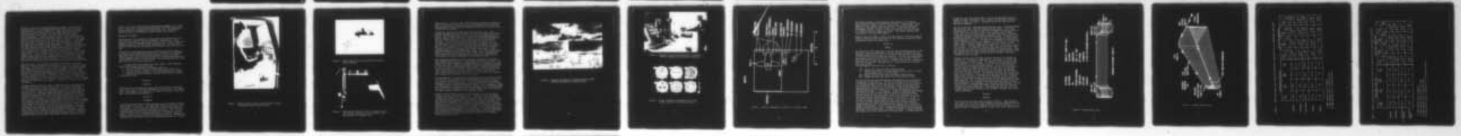
AD-A034 724　AIR FORCE ACADEMY COLO　F/G 1/2
HELMET MOUNTED DISPLAYS AS AN ALTERNATE SOURCE OF FLIGHT INFORM--ETC(U)
JAN 77　E H GALLUSCIO, J E RASINSKI
UNCLASSIFIED　USAFA-TR-77-1　NL

1 OF 1
AD-A
034 724



END
DATE
FILMED
3-7-77
NTIS

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

AD-A034 724

HELMET MOUNTED DISPLAYS AS AN ALTERNATE SOURCE OF FLIGHT INFORMATION

Air Force Academy, Colorado

January 1977

USAFA-TR-77-1

HELMET MOUNTED DISPLAYS AS AN ALTERNATE SOURCE OF FLIGHT INFORMATION

LT COL. EUGENE H. GALLUSCIO

MAJOR JOHN E. RASINSKI

CAPT. ROBERT G. EGGLESTON

JANUARY 1977

FINAL REPORT

D D C
RECEIVED
JAN 24 1977
RECEIVED
C

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DEAN OF THE FACULTY
UNITED STATES AIR FORCE ACADEMY
COLORADO 80840

32

Editorial Review by Lt Colonel Jack M. Shuttleworth
Department of English and Fine Arts
USAF Academy, Colorado 80840

This research report is presented as a competent treatment of the subject, worthy of publication. The United States Air Force Academy vouches for the quality of the research, without necessarily endorsing the opinions and conclusions of the authors.

This report has been cleared for open publication and/or public release by the appropriate Office of Information in accordance with AFR 190-17 and DODD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service.

This research report has been reviewed and is approved for publication.

Philip J. Erdle
PHILIP J. ERDLE, Colonel, USAF
Vice Dean of the Faculty

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (*and Subtitle*)
Helmet Mounted Displays as an Alternate Source of Flight Information.

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Eugene H. Galluscio, Major, USAF
Robert G. Eggleston, Captain, USAF
John E. Rasinski, Major, USAF

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Department of Behavioral Sciences and Leadership
United States Air Force Academy

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)
AMRL/HEA
Wright Patterson AFB, Ohio

15. SECURITY CLASS. (*of this report*)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)
Distribution of this document is unlimited.

D D C
JUN 24 1977
C

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)
Helmet Mounted Displays
Visual Systems
Flight Simulation
Divided Attention
Target Detection

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

The potential use of Helmet Mounted Displays (HMD) as an alternate source of flight information was examined. Air Force T-41 instructor pilots were trained to perform two complex flight maneuvers in a GAT 1 flight simulator using a monocular visor-projected display as the sole source of aircraft flight information. A search pattern and weapons delivery maneuver were flown utilizing standard aircraft instruments. The pilot flew the maneuvers under four experimental conditions:

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

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

Block #20

(1) Referencing the simulator instruments only, (2) Referencing the simulator instruments with selected instruments occluded, (3) Referencing the helmet display only, (4) Referencing the helmet display with selected instruments occluded. It was determined that the subjects were able to transition to the helmet display with little difficulty. The subjects were able to control the simulator with equal precision under all experimental conditions. It was found that on secondary tasks requiring divided attention between the flight instruments and events outside the cockpit, there was a tendency for the subjects to perform better when not using the HMD. This was attributed to minor perceptual problems associated with dichoptic viewing. Additionally, it was determined that overall performance increased when the number of instruments available to the pilot was decreased to an essential minimum. This result was explained in terms of signal density during divided attention tasks.

TABLE OF CONTENTS

SECTION PAGE

I. INTRODUCTION 1

II. SUBJECTS 6

III. APPARATUS..................................... 6

IV. METHOD 13

V. RESULTS 14

VI. DISCUSSION 19

LIST OF FIGURES

FIGURE PAGE

1. Subject seated in GAT 1 flight simulator wearing the Hughes Aircraft Helmet Assembly 7

2 Target aiming reticle projected onto simulator front windscreen 8

3. Photoresistor feedback device for weapons delivery task showing light source on tail of GAT 1 and photoresistor on laboratory wall 8

4 Composite photograph of background scene showing position and sequence of search targets 10

5. Research control room showing GAT 1 instructor station, programming and recording equipment 11

6. Flight instrument arrangement used in GAT 1 flight simulator and instructor station 11

7 General arrangement of simulator and control rooms. 12

8 Search pattern task 15

9 Weapons delivery task 16

LIST OF TABLES

TABLE PAGE

1 Search task mean error scores and statistical comparisons for all experimental conditions 17

2 Weapon release task mean scores and statistical comparisons for all experimental conditions 18

SECTION I

INTRODUCTION

PREVIOUS RESEARCH

Many of the latest aircraft cockpit design features have been concerned with increasing the amount of visual information available to the pilot. These new cockpit designs are considered necessary if a pilot is going to maintain his ability to successfully interface with today's sophisticated aircraft systems. One line of research dealing with this man-machine interface has recognized the ever increasing demand for an improved visual information processing system to facilitate pilot control of today's complex aircraft systems while simultaneously allowing him to attend to events external to the cockpit. Research in this area has reflected the innovative, creative thinking which is necessary in dealing with the complex problems associated with modern aerial flight. Two of the approaches directed at extending the pilot's visual information processing capacity which have gained support are the Helmet-Mounted Display (HMD) and the Heads Up Display (HUD) systems.

An HMD is a device which uses a miniature cathode ray tube and an optical system to portray information to the pilot. Usually, this display is projected to only one eye, thus freeing the other eye for viewing outside of the aircraft, or for viewing other displays inside the cockpit. The HUD system provides a heads-up capability by projecting information at windscreen level and in such a manner as to allow the pilot to view the displayed information or to see through it to the outside world.

The HMD system has a number of advantages over the HUD. Most obvious is that it provides the pilot with both a heads-up capability and an unrestricted freedom of head movement. The greater mobility provided by the HMD system permits the pilot to see the displayed information either on or off the boresight line of the aircraft. With the HUD display, the device is in a fixed position, usually on the aircraft axis above the instrument panel, requiring the pilot to orient to the display (Hughes, Chason, and Schwank, 1973). In addition, the HMD does not take up primary cockpit space and it has the potential of being coupled with other helmet-mounted systems which could extend the operational parameters of the combat pilot (Chason, Schwank, and Hughes, 1973).

There are some potential difficulties associated with the use of HMD systems that must be considered along with their potential benefits. In 1969, Miller reviewed some of the technical problems associated with HMDs including the problems of daylight versus night systems, weight considerations, and display detail. More importantly, Miller suggested some potential human problems related to the use of HMDs. These included problems associated with presenting different images to each eye simultaneously and also the very important consideration of pilot acceptance.

A detailed examination of the psychological and perceptual problems associated with HMDs may be found in Psychological Considerations in the Design of Helmet-Mounted Displays (Hughes, Chason, and Schwank, 1973) and a comprehensive survey of the technical developments and potential applications of HMDs has been published in Proceedings of: A Symposium on Visually Coupled Systems: Development and Application (1972, 1973). Thus this material will not be covered in detail in this paper.

Prototype HMDs have used various design concepts. All of the display configurations in use can be divided into three main types, regardless of whether the display is side mounted or visor projected on the helmet (Shontz and Trumm, 1969). The one-eye, occluded system presents the pilot with a monocular view of the outside world and a monocular view of the display. The one-eye, see-through system permits a binocular view of the outside world and a monocular view of the display imagery. Finally the binocular see-through system presents a binocular view of both the outside world and the display imagery. A modification to the configurations just listed is the bifocular display which presents the HMD imagery off center and requires the pilot to move his eyes in order to see the display. The bifocular design eliminates many of the perceptual problems associated with the other systems but also eliminates the possibility of simultaneous visual processing and may be considered to be a compromise between the HUD and the continuously present HMDs.

The binocular see-through system creates serious problems for information processing and in the side mounted configuration severely restricts the field of view to the point that pilot acceptance seems highly unlikely (Shontz and Trumm, 1969). The restricted field of view created by a simulated side mounted display resulted in a significant decrease in the ability of subjects to detect peripherally presented targets (Chason, Schwank, and Hughes, 1973), further reducing the desirability of the side mounted HMD configuration.

The monocular visor configurations, which seem more likely to achieve pilot acceptance, still present some critical human performance questions (Hughes, Chason, and Schwank, 1973). With the monocular visor see-through display, the pilot must at times process a binocular view of the world and a monocular view of the display information. At other times, only one eye sees through to the outside world while the other is focused on the displayed information. This latter condition presents a true dichoptic viewing task. How the simultaneous presentation of visual information under both of these viewing conditions effects performance must be determined.

Two visual information processing tasks may be attempted when different stimuli are presented simultaneously to each eye. The subject may attempt to process and respond to the signals received by one eye while ignoring, or at least attentuating, signals received by the other eye. This is called focused attention. On the other hand, the subject may attempt to simultaneously process and respond to the signals received by each eye. This is called divided attention (Treisman, 1969). Both types of selective attention may be anticipated under monocular HMD conditions.

The effects of selective attention have often been investigated by analyzing differences in the psychological refractory period (PRP). PRP refers to the time required by a subject to respond to one of two stimuli presented simultaneously or in rapid serial order. The PRP task, therefore, creates a situation which closely resembles a focused attention task. That is, the subject must attend to one stimulus while a second stimulus is also being presented. Using simple visual stimuli in a PRP task, Sanders (1971) reported that a response delay occurs when a response to the second signal is required, if it follows the first in close temporal order. The same decrement in response time was noted when a response to the first of two rapidly presented signals was required (Kantowitz, 1969).

Goldstein and Allen (1971) demonstrated that in binocular viewing the presence of irrelevant stimuli effects the psychological refractory period. They found that non-salient stimuli increased the reaction time of their subjects and increased the probability of error as well. Their study may be related to a focused attention task when the HMD user must react to the outside world while the helmet display imagery is seen as irrelevant stimuli or vice versa.

A variant of the standard PRP paradigm requires a separate subject response to each signal presented. With this modification the PRP task resembles a divided attention task under HMD viewing conditions. Research using this design indicates that there is usually a large delay in one of the two responses (Keele, 1973). It must be noted, however, that these results refer to binocular viewing of simple visual stimuli and thus may not be applicable to the dichoptic viewing of complex imagery presented in the HMD situation.

A recent series of experiments by Schwank (unpublished dissertation, 1975) examined a number of psychological problems associated with using an HMD. Schwank conducted six experiments, all of which used the PRP paradigm and required the subject to make separate responses to different stimuli presented simultaneously to each eye. These experiments were designed to directly compare dichoptic viewing (divided attention) with binocular viewing. His first experiment used simple visual stimuli presented against a dark background and produced a significant response time decrement in the dichoptic viewing condition. This decrement was on the order of 20 milliseconds. Perhaps more importantly there was no significant difference in error rate between binocular and dichoptic viewing. Thus accuracy of responding does not seem to be impaired by dichoptic viewing even though there is a small increase in response time. An additional finding from this research was the apparent lack of signal fusion or signal rivalry under dichoptic viewing. This is an important finding since either signal fusion or rivalry would seriously hinder performance under HMD viewing conditions.

Schwank's second experiment increased task complexity by a factor of two. The greater stimulus complexity did not increase error rate or reaction time as a result of dichoptic viewing This suggests that the results from research using relatively simple visual tasks may be applicable to a more complex visual environment such as that which would normally confront the HMD user.

The question of spatial compatibility between signal location and location of the response switch is of considerable importance in the use of an HMD. As Schwank pointed out, "compared to a binocular environment, a right-eye (monocular) signal in a dichoptic environment may be more likely to lead to a forward control stick movement with the right hand instead of the desired forward throttle movement with the left hand". (p.3 unpublished dissertation 1975). In two studies which manipulated spatial compatibility, Schwank found, with one exception, no significant difference between dichoptic and binocular viewing in terms of reaction time. The one significant reaction time difference favored binocular viewing; however, as Schwank stated this result was probably due to a speed-accuracy tradeoff difference and not related to dichoptic versus binocular viewing.

In one of his experiments, Schwank simulated a focused attention task. In this experiment the subject had to continuously respond to signals from one display while monitoring a second display which normally presented irrelevant stimuli but occasionally (10% of the time) presented a relevant stimulus requiring a response. A similar situation exists when a pilot focuses his attention on one instrument and periodically cross checks his other instruments and sometimes finds that he must make a corrective response based on the information gained from the cross check. Results from Schwank's experiment indicate a slight, (approximately 20 milliseconds), but significant, reaction time increase with dichoptic viewing under this condition. This slower reaction time amounts to approximately a 5% performance decrement. It remains to be seen whether this slight decrement in response time will be of any practical significance effecting a pilot's control of an aircraft.

Three studies of divided attention under binocular viewing conditions are particularly relevant to divided attention under HMD conditions in flight. Baddely (1972), in a study of divided attention in deep-sea divers, concluded that the inclusion of stress focuses the individual's attention on the primary aspects of the task with a resulting improvement in performance; however, performance was degraded on peripheral tasks. Hockey (1970a, 1970b) found that high intensity noise affected divided attention by improving performance on a primary visual tracking task while deteriorating performance on a secondary visual monitoring task. These studies suggest that divided attention between HMD imagery and the outside visual environment may be affected by stress conditions commonly found in flight such as high noise and a hostile environment. For a comprehensive survey of the selective attention literature and its relationship to HMD utilization, refer to Selective Attention: An Annotated Bibliography by Schwank and Chason (AMD Technical Report, in press).

Galluscio, Swiney, and Klusman (AMD Technical Report, in press) evaluated the efficacy of a side-mounted HMD as the sole source of flight information on a simulated flight task. Both experienced pilots and novice pilots flew a simulator on a prescribed course and were required to detect targets (small dots of light) portrayed against a terrain background. Significantly fewer targets were detected by the instructor pilot group when the HMD was used for portraying flight information, but this was not true for the novice pilot group. It was noted that the number of targets missed under both see-through and occluded HMD conditions closely paralleled the number of targets portrayed on the same side of the pilot as the HMD mounting. Therefore, the reduction in target detection under the HMD viewing conditions was probably the result of the limited viewing created by the side-mounted hardware. This interpretation is supported by other research (Chason, Schwank, and Hughes, 1973). The low target error rate in the Galluscio, et al. study suggests that retinal rivalry, retinal fusion, or brightness disparity did not seriously affect pilot performance when searching for targets while using the HMD for flight information. This finding is in agreement with the results reported by Schwank (unpublished dissertation 1975).

Galluscio et al. also evaluated flying proficiency under conditions where all flight information was presented on an HMD or a standard instrument panel. Mean deviations in altitude, air speed, and heading control were analyzed and resulted in only minor decrements in aircraft control under both the one eye occluded and see-through HMD conditions. Mean deviation in heading control appeared to be most affected by HMD viewing, but this deviation was minor. Therefore, in general, the Galluscio et al. findings indicate that flying proficiency is not seriously affected by the use of an HMD as the sole source of flight information. Thus, it would seem that the HMD device has a potential usefulness as a source of flight information.

Although the Galluscio et al. study extends the research on focused and dichoptic viewing with an HMD from a static to a dynamic environment, it still leaves many questions unanswered. First, their study used a very simple task. The pilot simply had to maintain a constant heading, altitude, and air speed while detecting targets. What would happen to flying proficiency with HMD portrayed flight information during a more complex flight maneuver? Secondly, most targets were presented on the front axis of the aircraft. A similar target detection task would be more difficult if targets were presented off the boresight of the aircraft. This situation would make better utilization of the flexibility of an HMD and therefore should show the maximum gain that could be expected from using an HMD as an alternate source of flight information. This situation would also allow for a test of the potential problems associated with changes in pilot frame of reference under HMD conditions. Jacobs, Triggs, and Aldrich (1970) point out that errors in spatial orientation may result when a pilot is processing HMD information while his head is turned off the line of flight. With either a right or left head orientation, a roll error could be misinterpreted and responded to as a pitch error. This error in interpretation would most likely occur when pilot head orientation is 90 degrees off the aircraft axis. This potential problem of spatial orientation also needs further investigation.

Purpose of the Study

The purpose of this study was to further define the effectiveness of an HMD as the sole source of flight information. Additionally, a more advanced visor projected HMD display system was used in place of the side-mounted cathode ray tube HMD used by Galluscio et al.; thus one other concern of the study was to evaluate the efficacy of this version of the HMD.

Although it has been demonstrated that proficient simulated flight can be maintained under HMD viewing conditions, it remains to be determined under what flight conditions an HMD will permit a pilot to maintain flight parameters while providing the benefit of simultaneous viewing of the environment external to the aircraft. The study addressed this issue. Specifically this study was designed to:

1. Evaluate HMD effectiveness under more complex flight conditions than has been previously demonstrated.
2. Test the HMD under pure instrument conditions.
3. Evaluate various instrument configurations under HMD viewing.
4. Determine pilot acceptance of the visor projected visual system.
5. Identify perceptual problems associated with dichoptic viewing in simulated flight.

SECTION II

SUBJECTS

The subjects for the study were eight USAF pilots serving as instructor pilots in the T41C aircraft who volunteered to participate in the experiment. They ranged in age from 28 to 35. Mean T41 and total flying time were 165 and 2450 hours respectively.

SECTION III

APPARATUS

The flight simulator used for the experiment was a Link General Aviation Trainer (GAT-1) (Figure 1). This device has 3 degrees of motion, pitch, bank and yaw. The simulator was fitted with a device which projected a gunsight and reticle onto the windscreen (Figure 2). The reticle was illuminated with a white light except when the simulator was "on parameters" at which time a signal was generated by an automatic photocell device located on the wall behind the simulator (Figure 3). Whenever the simulator was being flown at precisely predetermined parameters, a small

Figure 1. Subject seated in GAT 1 flight simulator wearing the Hughes Aircraft helmet assembly.

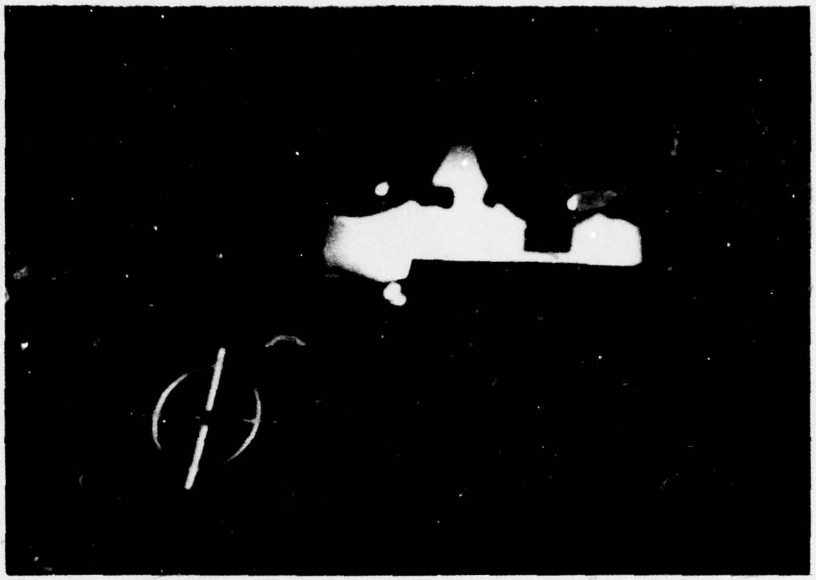


Figure 2. Target aiming reticle projected onto simulator front windscreen.

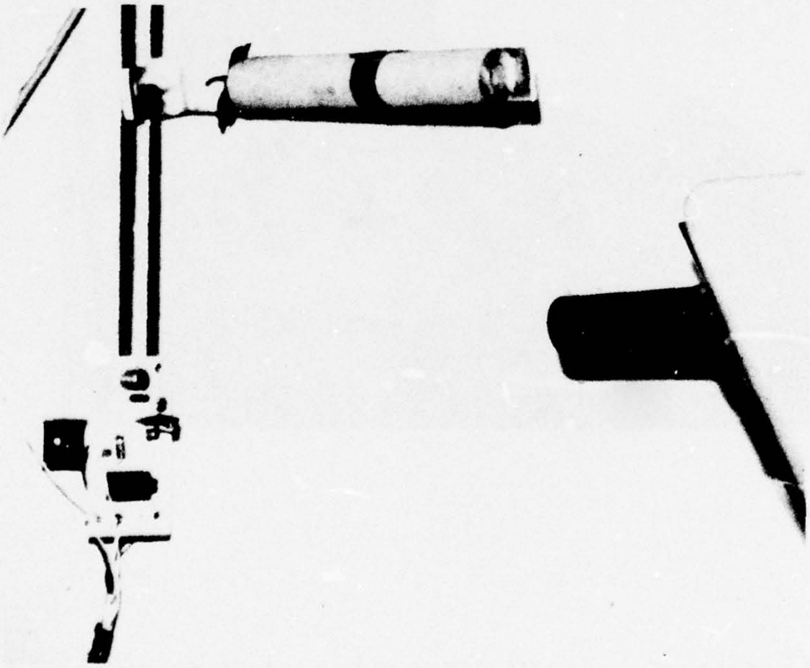


Figure 3. Photoresistor feedback device for weapons delivery task showing light source on tail of GAT 1 and photoresistor on laboratory wall.

light source in the tail of the simulator would illuminate the photocell which in turn would provide the signal that illuminated the reticle red. Thus the subject was provided with immediate feedback when he was on the predetermined parameters.

A frame was erected on the west wall of the simulator room. White material was then tacked to the frame providing a 2.8 meter by 5.2 meter screen. Four colored slides taken in the local area (representing a typical scene as viewed from a T41 cockpit) were projected and matrixed onto the screen (Figure 4). Targets for the tasks were provided in two ways; 1) for the simulated dive bomb task, the target was a 2 centimeter spot of light projected onto a black background. The spot was precisely located so that when the subject superimposed the reticle over it, at an appropriate dive angle and heading, the reticle would illuminate red; 2) for the search task, targets were spots of light projected randomly onto the background scenery. The target stimuli were made by drilling precision holes in black 35MM slides. The holes were made so that when a slide was projected, a white dot of approximately 2 centimeters in diameter appeared on the background scenery.

Each target presentation was 300 milliseconds in duration and targets were sequenced automatically by a BRS Foringer binary logic system. The target slides were programmed at random intervals, half occurring on each side of the screen. Subjects responded to targets by depressing a button on the left side of the simulator control wheel. A button press during the two second period following target presentation interval pulsed the logic system indicating a correct response. A button press at any other time produced an error indication. All correct and error responses were automatically totalled by the logic system.

The room adjacent to the simulator was equipped with an instructor console for the GAT-1 that included an instrument display identical to that in the simulator (Figures 5,6 and 7). A high resolution television camera mounted near the instrument console was used to transmit a picture of the instrument console to the helmet mounted display. This arrangement allowed the experimenter to completely cover the instrument panel in the simulator, thus excluding all information to the subject except that coming from the instructor console through the helmet mounted display.

Subjects wore the Hughes Aircraft Helmet Assembly with the visor down (Figure 1) during all experimental runs. Televised flight instruments included the altimeter, airspeed indicator, vertical velocity indicator, altitude indicator, heading indicator, and turn and slip indicator. When the televised instruments were displayed to the subject, they were displayed to his right eye on a transparent screen mounted on the inside of the helmet visor. The screen allowed the subject to attend to the instruments or look through the screen at the target. Picture resolutions was sufficient to accurately read all the instruments. Simulated radio noise was fed through the earphones of the helmet assembly and simulated engine noise inside the GAT-1 provided 79 decibels masking of the equipment external to the simulator.

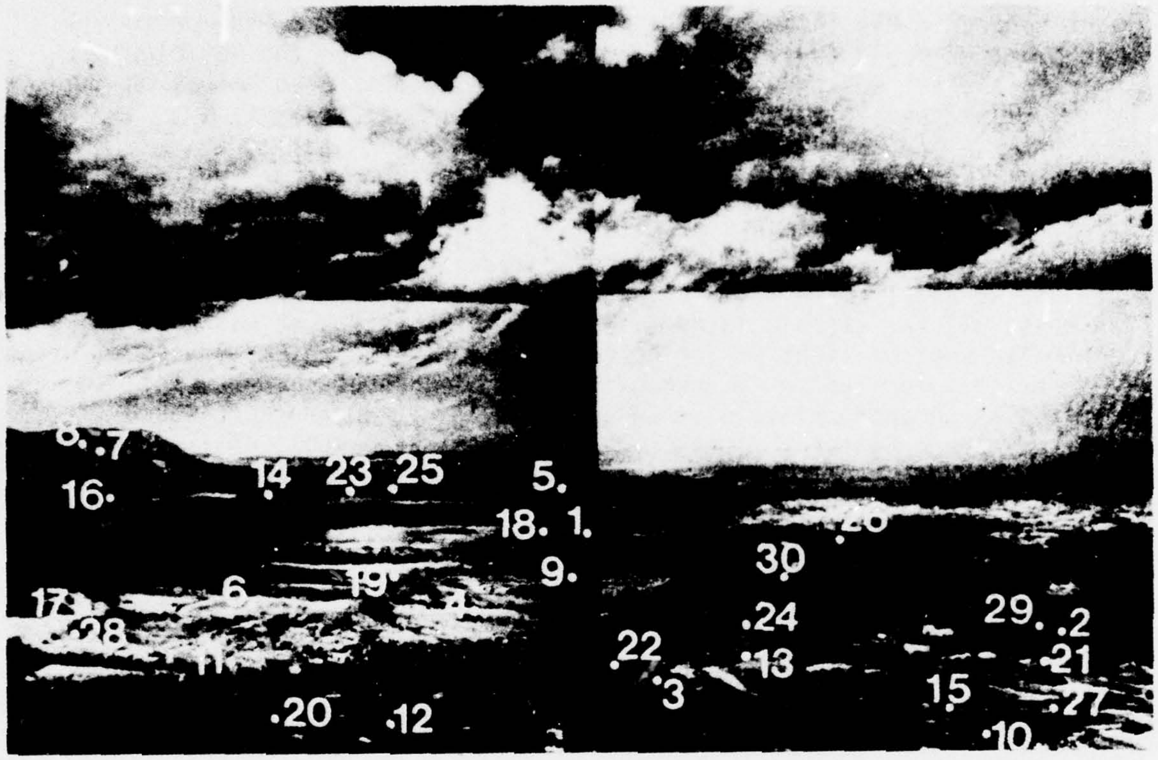


Figure 4. Composite photograph of background scene showing position and sequence of search targets.

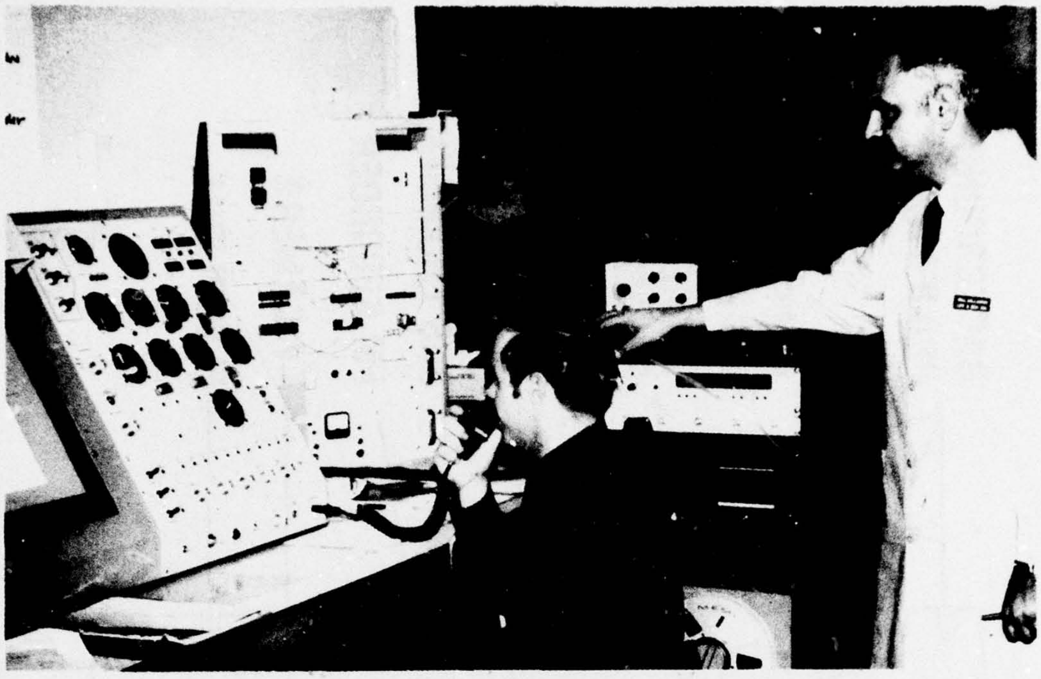


Figure 5. Research control room showing GAT 1 instructor station, programming and recording equipment.

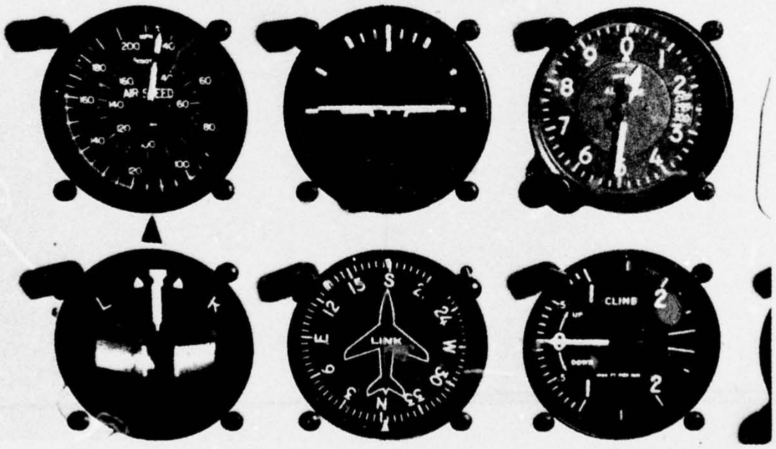


Figure 6. Flight instrument arrangement used in GAT 1 flight simulator and instructor station.

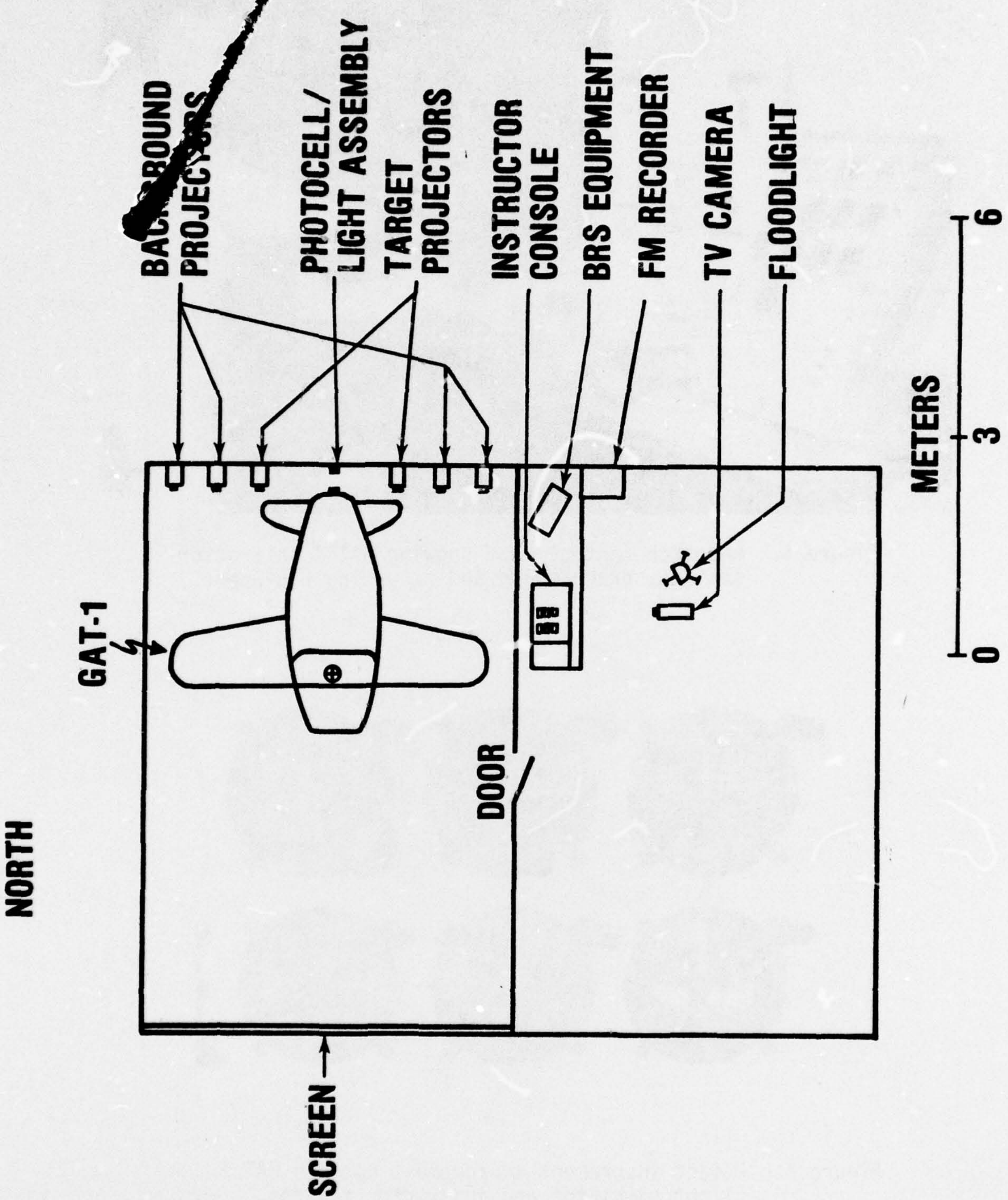


Figure 7. General arrangement of simulator and control rooms.

The flight parameters of the simulator were recorded in the form of analog data on an Ampex FR-1300 FM tape recorder. Analog output for airspeed, altitude, heading, vertical velocity, and on target signal were continuously recorded for each subject trial. These data were then transformed, through an analog to digital conversion, onto digital tape at a sampling rate of 5 samples per second. The digital data was then processed by a Burroughs 6700 computer.

Ambient light in the GAT-1 cockpit was 2 foot candles. One foot candle of light was reflected from the screen used for background scenes and target presentations during the search task.

SECTION IV

METHOD

The instructor pilots were given a one hour familiarization session in the simulator. They were permitted to fly the simulator throughout its performance envelope to get a feel for the device. Additionally, each subject was familiarized with the HMD device controls. Sessions two through seven were practice sessions with the full instrument panel display. Session eight was the full panel test session. Sessions nine and ten were practice sessions with a partial instrument panel. Session eleven was a partial panel test session.
The experimental conditions were as follows:

STH - Search task using the helmet mounted display
ST - Search task without the helmet mounted display, that is, using the instrument panel in the simulator
WDH - Weapons delivery task using the helmet mounted display
WD - Weapons delivery task without the helmet mounted display

The first of the two tasks performed by the subjects was the search task, a simulated daylight mission. Its initial parameters were an altitude of 3000 feet, airspeed of 105 miles per hour, constant vertical velocity, and a heading of either 360 or 180 degrees, thereby always keeping the landscape out of the west side of the cockpit. During the three minute leg, the subject had to maintain all of the initial parameters while searching for targets on the landscape. Target presentations were changed each session by starting the projector carousel at random positions. During training for the search task, targets were presented onto the terrain portion of the background scene at a mean rate rate of one each 12 seconds (periods ranged randomly from 4 to 18 seconds). During testing, 30 targets were presented to each subject on one 6 minute test leg, with the same targets being used under both viewing conditions. Target duration was 300 milliseconds and the subjects had 2 seconds to respond to each target. Figure 4 shows the sequence and location of the targets presented on test day. The dependent variables were the absolute deviations in altitude, heading, airspeed, the number of targets detected and target error scores during the six minute period. To change direction between the legs, the subject made a right or left 90 degree turn (20 degrees of bank) followed by a left or right 270 degree turn, always to the west as shown in Figure 8. Parameters during the turns were not measured or recorded.

The second task was a simulated weapons delivery task, a nighttime mission with no visual cues in the test room except the target. Its initial parameters were an altitude of 3000 feet, airspeed of 80 miles per hour, level flight (zero vertical velocity), and a heading of 360 degrees. In the dark room, the subject made a descending left bank and turn and sighted on the target being projected onto the screen. He aimed for and maintained parameters of 140 miles per hour, 1500 feet per minute down, and 270 degrees of heading. The subject also attempted to keep the boresight illuminated red as long as possible. At 1500 feet of altitude, the subject made a simulated weapon release by pushing a button on the control wheel. He then climbed back to 3000 feet. The pattern is depicted in Figure 9. The dependent variables were absolute deviations from required vertical velocity, airspeed, heading, and time on target. These were recorded from the time the aircraft passed through 2500 feet during the descent until the weapon release button was pushed or 1400 feet indicated altitude occurred.

Practice sessions were 50 minutes long and consisted of 10 minutes of condition ST, 10 minutes of condition STH, 15 minutes of condition WD, and 15 minutes of condition WDH. The sequence of the four tasks were varied randomly for each subject so as to partially counterbalance the conditions for practice and fatigue effects. During each 50 minute session subjects averaged 4 weapon delivery runs and 2-3 minute search runs per subject per condition per day. On test day, three weapons delivery tasks were flown and one 6 minute long search leg was flown under each viewing condition. The direction of flight was assigned randomly to each subject. During the ninth and tenth sessions (the partial panel practice sessions), the subject was permitted to view a limited number of instruments for both the with and without helmet mounted display conditions. The instruments selected for the abbreviated tasks were made subjectively and represent those instruments absolutely necessary to give feedback on the dependent variables which were measured. For the search task, the instuments the subjects could see were the altimeter, airspeed, and heading indicators. For the weapons delivery task, the visible indicators were limited to the altimeter, airspeed, and vertical velocity indicators.

SECTION V

RESULTS

The results for the search task are given in Table 1. Mean absolute error scores for the three flight parameters and mean target acquisition and target error scores are shown on the left side of the table. An overall F test for repeated measures on the flight scores indicated that

ALTITUDE	3000 FT (2000 FT AGL)
AIR SPEED	105 MPH
VVI	CONSTANT
MAJOR HEADINGS	360° & 180°
TURN RATE	30° BANK
LEG TIME	3 MINUTES
TARGETS	15 PER LEG (RANDOM INTERVAL)

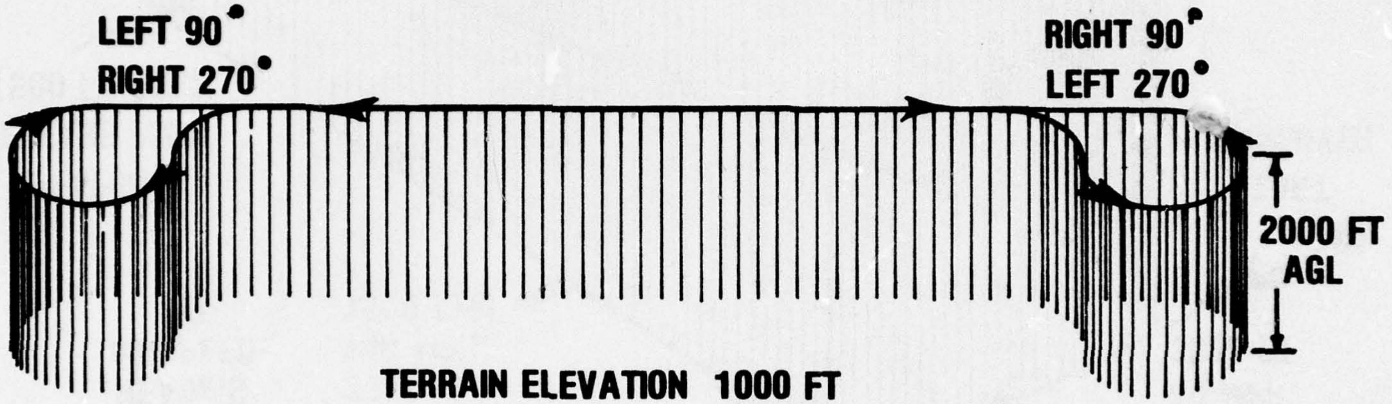


Figure 8. Search pattern task.

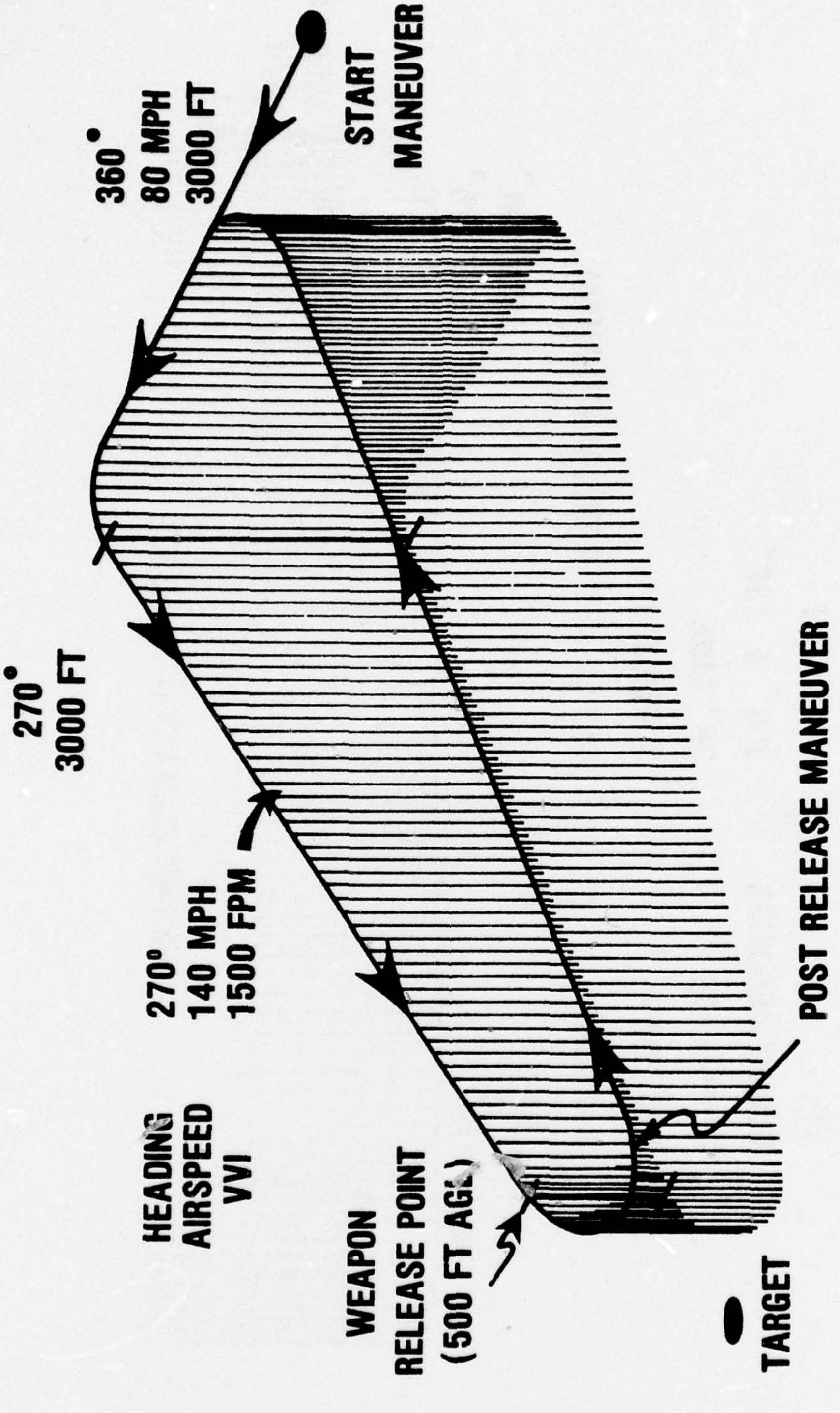


Figure 9. Weapons delivery task.

TABLE 1. Search task mean error scores and statistical comparisons for all experimental conditions.

	EXPERIMENTAL CONDITIONS				STATISTICAL COMPARISONS			
	STH FULL	ST FULL	STH ABB	ST ABB	STH FULL ST FULL	STH ABB ST ABB	STH FULL STH ABB	ST FULL ST ABB
HEADING*	3.55	3.57	3.17	2.77	F 0.003 p NS	F 0.402 p NS	F 0.233 p NS	F 1.958 p <.25
AIRSPEED**	2.08	2.29	3.37	3.10	F 0.035 p NS	F 0.355 p NS	F 0.540 p NS	F 0.003 p NS
ALTITUDE***	44.76	58.92	69.01	89.52	F 1.628 p <.25	F 4.240 p <.10	F 2.629 p <.25	F 2.395 p <.25
TARGETS	19.38	20.38	21.63	22.13	t 1.15 p NS	t 0.49 p NS	t 1.56 p <.25	t 1.69 p <.25
ERRORS	1.88	0.50	1.25	0.63	t 2.55 p< .05	t 1.48 p <.25	t 1.04 p NS	t 0.22 p NS

* Mean absolute error in degrees

** Mean absolute error in miles per hour

*** Mean absolute error in feet per minute

TABLE 2. Weapon release task mean scores and statistical comparisons for all experimental conditions.

	EXPERIMENTAL CONDITIONS				STATISTICAL COMPARISONS			
	WDH FULL	WD FULL	WDH ABB	WD ABB	WDH FULL WD FULL	WDH ABB WD ABB	WDH FULL WDH ABB	WD FULL WD ABB
HEADING*	3.40	2.78	3.33	2.88	F 1.928 p <.25	F 0.394 p NS	F 0.002 p NS	F 0.092 p NS
AIRSPEED**	4.02	4.10	4.57	3.86	F 0.000 p NS	F 3.357 p <.25	F 2.176 p NS	F 0.086 p NS
VERTICAL*** VELOCITY	124.51	114.56	128.03	115.10	F 0.150 p NS	F 6.3.30 p <.05	F 0.006 p NS	F 0.007 p NS
TIME ON**** TARGET	5.68	6.16	6.58	10.29	t 0.29 p NS	t 1.13 p NS	t 0.69 p NS	t 1.42 p <.25

* Mean absolute error in degrees

** Mean absolute error in miles per hour

*** Mean absolute error in feet per minute

**** Mean time on target in seconds over three weapons maneuvers there were no significant differences between the experimental conditions. Individual post-hoc F tests for repeated measures were performed for each flight parameter dependent variables. None of the resulting twelve comparisons were significant. The only comparison to approach significance was altitude control in the abbreviated instrument condition. There was a slight tendency for better altitude control in the HMD viewing condition ($F = 4.240$, df = 1/7, $p < .10$). T-tests for repeated measures were made on the search target and error scores. Only one of the resulting eight comparisons was significant. In the full instrument condition there was a tendency for the pilots to make more target errors while flying with the display ($t = 2.55$, $p < .05$). Examination of Table 1 shows that there was a tendency for the subjects to acquire more targets while flying with the abbreviated instruments under both viewing conditions but these differences failed to reach significance.

The weapons delivery task data are given in Table 2 and represent average scores for all three weapons delivery runs made on the test days. Flight parameters are given as mean absolute deviations and the time on target scores are in seconds. An overall F test on the flight data was not significant. Individual post-hoc F tests for each flight dependent variables were made. Only one of the twelve resulting tests was significant. In the abbreviated instrument condition, control of vertical velocity was better when the subjects were flying with the simulator instruments as compared to the helmet display ($F = 6.330$, df = 1/7, $p < .05$). For the time on target data t-tests for repeated measures were made and none of the comparisons were significant. Examination of Table 2 shows that mean time on target scores tended to be better in the abbreviated instrument conditions, but the t-tests failed to reach significance.

A discriminant analysis was made on the flight data for both the search and weapons delivery tasks. None of the applied weights increased the significance levels for either of the analyses.

SECTION VI

DISCUSSION

Evaluation of the search task data supports the notion that the helmet display is an adequate source of alternate flight information for this type flight maneuver. In fact, four of the six comparisons between helmet display viewing and instrument panel viewing showed a tendency for better aircraft control utilizing the helmet. It is interesting to note that a decrement in altitude and airspeed control was evident in the abbreviated instrument conditions. This finding could have been predicted since the vertical velocity indicator was not available in these experimental conditions. This is the first instrument to give feedback on altitude change because the altimeter is subject to considerable lag. Of course, airspeed and altitude are not independent, especially in a fixed pitch, light aircraft such as the T-41 and we would expect to see concurrent errors on these dependent variables.

Although only one of the statistical comparisons for the target data was significant, several trends seem to be apparent. First, in both full and abbreviated instrument conditions there was a tendency for the pilot to find slightly fewer targets when using the helmet display. This is somewhat consistent with the results obtained by Galluscio, et al. (1975). They attributed the significant differences in target detection to peripheral vision loss produced by the side mounted display used in that experiment. Apparently the unobstructed viewing afforded by the visor projected display reduces this problem, but does not completely eliminate it. The slight reduction in target acquisitions under the helmet viewing condition is probably attributable to the dichoptic viewing condition and partial masking of the right eye by the HMD imagery.

A second notable trend in the target acquisition data was the tendency for the subjects to have more error scores in the helmet viewing conditions. In the full panel condition these differences were statistically significant. This finding is in partial agreement with earlier research (Galluscio, et al. 1975) where the tendency for more target errors was evident under helmet display conditions. In that study, the target error differences were not significant and the researchers concluded that if the task had been made more difficult by decreasing the target dwell time, the differences "could have reached significance" (Galluscio, et al. 1975). In this study the target dwell time was 300 milliseconds compared to 2 seconds in the earlier study. The significant error differences are most likely due to increased PRP times found under dichoptic viewing conditions (Schwank, unpublished dissertation, 1975). It should be noted, however, that the total error scores made under all conditions were very small and may not have pragmatic significance.

A third factor that deserves attention in the target acquisition data is the tendency for the pilots to find more targets when flying with the partial instrument display. This was the case for both helmet and instrument panel viewing. It appears that when visual loading was reduced in this divided attention task, the subjects were more successful in processing the visual inputs from outside the simulator. This conclusion seems entirely logical in that instrument cross checks were much simplified in the abbreviated instrument conditions and therefore, required less time, allowing more rapid altering of attention between flight instruments and the external environment.

The results from the weapons delivery task indicate that the helmet display may be a viable alternative to the aircraft instruments on this very complex flight maneuver. Essentially no differences in flight performance could be seen between helmet display viewing and referencing the simulator instruments on this task. Control of vertical velocity was better under instrument panel viewing and this difference was statistically significant in the abbreviated instrument conditions. It should be noted, however, that the error differences were only 13 feet per minute on an instrument that is marked in 100 foot per minute increments. This merely points out that the variance within each condition was very small and that the flight performance differences observed may not be of practical significance.

The time on target data are interesting. Performance tended to be somewhat better when using the instrument panel as compared to the helmet display, and the abbreviated instrument conditions improved performance. Why time on target performances would tend to be better while using the instrument panel is not clear. The improvement of performance with the abbreviated instruments complements the results of the search task. It appears that when the pilots must alter their attention between the flight instruments, the aiming reticle, and the target, it is helpful to reduce the amount of flight information available for processing. Eliminating the non-essential instruments from the instrument cross check improved time on target performance without adversely effecting flight performance.

Several questions should be considered at this time. First, were the dependent variables in this study sensitive enough to detect real differences between the experimental conditions? The answer is an unequivocal, yes. Tests for significance between subjects resulted in many significant comparisons. These were not reported because they were not relevant to the purpose of this research effort but they do serve to demonstrate the power of our dependent variables when real differences do exist. Secondly we should consider whether the results of this research will generalize to actual flight conditions or even to more sophisticated, high performance simulators. Judging from the rapid and relatively easy transition to the helmet demonstrated by our subjects, and the equally successful use of HMD's by novice pilots in an earlier study (Galluscio, et al. 1975), this notion seems entirely plausible. Obviously, further research is needed to clearly demonstrate the potential value of HMDs in other vehicles and under other flight conditions. Finally, we should consider whether the tasks in this study were difficult enough to surface any potential performance decrements resulting from HMD viewing. The data would indicate that this was indeed the case. Although all subjects reached asymptotic performance on both tasks within the first five days of practice, their performance level varied considerably over the remaining training sessions. This, taken with the considerable differences in performance between subjects, strongly suggests that the tasks, especially the weapons delivery task, were difficult enough to adequately test the HMD's potential.

In summary, this study supports earlier research done at this laboratory (Galluscio, et al. 1975) which indicated that helmet display devices are potentially effective alternate sources of flight information. This study has demonstrated that experienced pilots adapt very quickly to the HMD imagery. Additionally, they are able to perform very complex flight maneuvers in the flight simulator using the HMD as the sole source of aircraft instrument information. Minor perceptual problems associated with the dichoptic viewing condition did not produce significant decrements in either flight performance or responses to stimuli external to the cockpit.

A second major finding of this research was that limiting the flight information presented to the helmet to only those instruments essential to the specific flight maneuver did not significantly affect flight performance. More importantly, the reduction of flight information improved performance on the secondary tasks (target acquisition and time on target) in the divided attention paradigm. It is tempting to suggest that additional simplification of the flight information, such as using heads-up display imagery on the HMD could further improve performance.

REFERENCES

Baddeley, A. D. Selective attention and performance in dangerous environments. British Journal of Psychology, 1972, 63, 537-546.

Birt, J. A. and H. L. Task (eds.) Proceedings of: A Symposium on Visually Coupled Systems: Development and Application, AMD-TR-72-1, Aerospace Medical Division, Brooks Air Force Base, Texas, December 1972.

Birt, J. A. and H. L. Task (eds.) Proceedings of: A Symposium on Visually Coupled Systems: Development and Application, AMD-TR-73-1, Aerospace Medical Division, Brooks Air Force Base, Texas, December 1973.

Chason, L. R., J. C. H. Schwank and R. L. Hughes Target vigilance effects from visual obstructions imposed by Helmet Mounted Displays. AMRL-TR-73-17, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio, August 1973.

Galluscio, E. H., J. F. Swiney and J. E. Klusman Control of flight and target vigilance utilizing a Helmet-Mounted Display as the sole source of aircraft flight instruments. AMRL, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, In Press.

Goldstein, I. L. and J. C. Allen Effects of irrelevant stimuli on the processing of information in complex displays. Journal of Applied Psychology, 1971, 35, 110-113.

Hockey, G. R. J. Effect of loud noise on attentional selectivity. Quarterly Journal of Experimental Psychology, 1970 a, 22. 28-36.

Hockey, G. R. J. Signal probability and spatial location as possible bases for increased selectivity in noise. Quarterly Journal of Experimental Psychology, 1970 b, 23, 22-42.

Hughes, R. L., L. R. Chason and J. C. H. Schwank Psychological considerations in the design of Helmet Mounted Displays and sights: overview and annotated bibliography, AMRL-TR-73-16, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, 1973.

Jacobs, R. S., T. J. Triggs and J. W. Aldrich Helmet Mounted Display/Sight Systems Study, AFFDL-TR-70-83, Vol. 1, Air Force Flight Dynamics Laboratory, Wright Patterson Air Force Base, Ohio, August 1970.

Kantowitz, B. H. Double stimulation with varying response information. Journal of Experimental Psychology, 1969, 82, 347-352.

Keele, S. W. Attention and Human Performance. Pacific Palisades, Ca.: Goodyear, 1973.

Miller, B. Helmet Mounted Display interest revived. Aviation Week and Space Technology, 24 Feb 1969.

Sanders, A. F. Probabilistic advance information and the psychological refractory period. Acta Psychologica, 1971, 35, 128-137.

Schwank, J. C. H. Dichoptic and binocular viewing effects on selective attention to dual-signal inputs. (unpublished dissertation), University of Oregon, 1975.

Shontz, W. D. and G. A. Trumm Perceptual Processes and Current Helmet-Mounted Display Concepts, TN-1, Research Department, Life Sciences Group, Honeywell, Inc., Minneapolis, Minnesota, April, 1969.

Treisman, A. M. Strategies and models of selective attention. Psychological Review, 1969, 76, 282-299.