

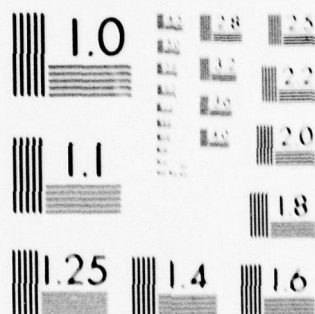
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USAARL REPORT NO. 78-5

VISUAL WORKLOAD OF THE COPILOT/NAVIGATOR
DURING TERRAIN FLIGHT

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By

Michael G. Sanders

Ronald R. Simmons

Mark A. Hofmann



December 1977

Final Report

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U.S. ARMY AEROMEDICAL RESEARCH LABORATORY
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flight, altitude and airspeed desired to traverse the course, and (3) identify hover points and checkpoints along the route which were given to the navigator in terms of six digit grid coordinates. Visual performance was measured via a modified NAC Eye Mark Recorder used in conjunction with a LOCAM high speed camera. This technique provided the means to objectively record and analyze the navigator's visual performance through the examination of: (1) visual time inside the cockpit on flight and engine instruments, (2) time inside the cockpit on the map or other navigation aids, and (3) time outside the cockpit in various windscreen sectors.

A visual free time task was utilized to determine the amount of visual time the navigator had available, during flight over the prescribed course, for a nonflight related task. The data indicate that the navigator's normal workload was demanding; the visual free time task was utilized only 3% of the total time. The data also indicate that the duty of navigating required 92.2% of the copilot's total visual time while the engine and flight instruments were utilized only 4% of the time. These data are discussed in relation to the copilot's specified duties.

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SUMMARY

The emphasis on aviator workload has been of primary concern to the U.S. Army aviation community since the incorporation of low altitude terrain flight techniques into the helicopter tactics repertory. Since navigation is a particularly acute problem at low altitudes, this project examined the visual workload of the navigator/copilot during terrain flight (nap-of-the-earth, contour and low level) in a UH-1H helicopter. The navigator's task was to: (1) perform a map study of the prescribed course, (2) direct the pilot during the flight as to the direction of flight, altitude and airspeed desired to traverse the course, and (3) identify hover points and checkpoints along the route which were given to the navigator in terms of six digit grid coordinates. Visual performance was measured via a modified NAC Eye Mark Recorder used in conjunction with a LOCAM high speed camera. This technique provided the means to objectively record and analyze the navigator's visual performance through the examination of: (1) visual time inside the cockpit on flight and engine instruments, (2) time inside the cockpit on the map or other navigation aids, and (3) time outside the cockpit in various windscreen sectors.

A visual free time task was utilized to determine the amount of visual time the navigator had available, during flight over the prescribed course, for a nonflight related task. The data indicate that the navigator's normal workload was demanding; the visual free time task was utilized only 3% of the total time. The data also indicate that the duty of navigating required 92.2% of the copilot's total visual time while the engine and flight instruments were utilized only 4% of the time. These data are discussed in relation to the copilot's specified duties.

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INTRODUCTION

The tactical requirement to conduct Army helicopter operations close to the earth has presented formidable navigation problems to Army aviators. Aviators forced to maintain aircraft masking while proceeding to enemy contact points, landing zones or MEDEVAC pick up points, have the difficult task of determining their position and navigating to and from these points with little aid in terms of salient landmarks and terrain features. Further, this problem is considerably increased with the need for round-the-clock all weather operations.

Pilot and copilot workload has increased significantly with utilization of tactical terrain flight techniques.

The increased workload experienced by the Army aircrew is due, in part, to the relative perceptual speeds at which terrain is traversed and the subsequent short periods of time that navigational cues remain in the visual field. Terrain flight consists of nap-of-the-earth (NOE), contour and low level flight profiles. These flight profiles have been defined as:

NOE. Flight as close to the earth's surface as vegetation or obstacles will permit, while generally following the contours of the earth. Airspeed and altitude are varied as influenced by the terrain, weather, and enemy situation. The pilot preplans a broad corridor of operation based on known terrain features which has a longitudinal axis pointing toward his objective. In flight, the pilot uses a weaving and devious route within his planned corridor while remaining oriented along his general axis of movement in order to take maximum advantage of the cover and concealment afforded by terrain, vegetation and man-made features. By gaining cover and concealment from enemy detection, observation and fire power, nap-of-the-earth flight exploits surprise and allows for evasive actions.

Contour. Flight of low altitude conforming generally and in close proximity to the contours of the earth. This type of flight takes advantage of available cover and concealment in order to avoid observation or detection of the aircraft and/or its points of departure and landing. It is characterized by a varying airspeed and a varying altitude as vegetation and obstacles dictate.

Low Level. Flight conducted at a selected altitude at which detection or observation of the aircraft is avoided or minimized. The route is preselected and conforms generally to a straight line and a constant airspeed and altitude. This method is best adapted to flights conducted over distances or periods of time.

The additional workload imposed on the aircrew during terrain flight has necessitated a division of duties. The pilot's primary responsibility during terrain flight has been the demanding task of maintaining clearance of the aircraft from all man-made and terrain obstacles as well as directing the aircraft over the desired route. The copilot, therefore, has assumed duties which entail, among other things: (1) monitoring the map and navigation instruments as well as the terrain in an attempt to locate the significant navigational cues needed for maintaining the correct flight path, (2) monitoring the helicopter engine instruments and other flight instruments, (3) tuning the radios, (4) orally providing navigational information to the pilot that will allow him to maintain the appropriate flight path, and (5) helping the pilot locate and avoid potentially hazardous terrain obstacles.¹

Workload has been defined as "the sum of the task demands which can be clearly specified, plus the operator's response (and effort) to satisfy these demands".² Pilot or navigator workload can be evaluated directly in terms of activity or effort on a primary task or indirectly by examining reserve capacity or time available for the performance of a secondary task.^{2,3} One specific approach for workload examination is in terms of visual demands upon the navigator (in this study) and the distribution of his visual time.

Previous studies have suggested that "frequency of eye fixation on any given instrument is an indication of the relative importance of that instrument. The length of the fixations, on the contrary, may more properly be considered as an indication of the relative difficulty of checking and interpreting particular instruments."^{4,5}

Recent research has identified the visual workload problems encountered by the pilot during straight and level flight at varying altitudes.⁶ This research demonstrated that "the duration and frequency of visual scan intervals change between NOE and 300 feet of altitude and that below 100 feet, any demands on the pilot's time can only be of the simplest type unless he is unburdened from his visual tasks."

Since the duties and responsibilities of the copilot have increased a great deal in a very short time frame, the objective of the current research project was to examine the existing visual workload (oculomotor performance) of the navigator/copilot during terrain flight.

METHOD

Subjects. Subjects participating in the investigation were ten recent graduates of the U.S. Army Initial Entry Rotary Wing flight training program of instruction at Fort Rucker, Alabama. These pilots

had recent training in navigation during terrain flight and an average of 287 total flight hours. All participants had at least 115 hours of flight experience in the UH-1H helicopter.

Apparatus. Oculomotor performance was recorded via a modified NAC Eye Mark Recorder used in conjunction with a 16mm LOCAM high speed motion picture camera. Through the utilization of the NAC Eye Mark Recorder, the aviator's viewing point was detected by means of an illuminated reticle reflected off the cornea of the eye. The optically focused reticle, reflected from the cornea, was superimposed upon a primary image with a field of view of 43.5° vertical and 60° horizontal. Figures 1 and 2 show a subject aviator wearing the modified Eye Mark Recorder.



Figure 1. Aviator Wearing the Modified NAC Eye Mark Recorder

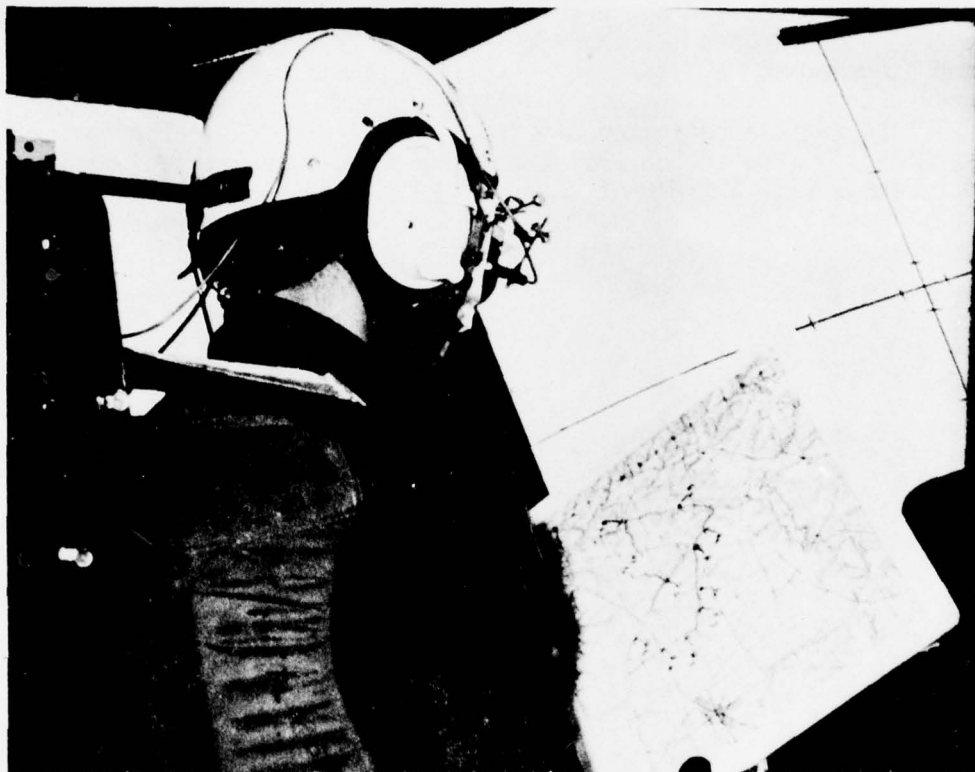


Figure 2. Copilot Prepared for Flight in the UH-1H Helicopter

One can also see the fiber optic bundle connecting the Eye Mark Recorder to the LOCAM 16mm camera, which is attached to the pilot's seat. A detailed description of the Eye Mark Recorder and scoring techniques utilized can be found in previously conducted USAARL research.^{7,8} The test vehicle was a JUH-1H helicopter.

The visual free time task utilized, which is similar to one utilized by Strother,⁶ consisted of a 5X7 card containing random monosyllabic words (reference Figure 3).

feed sly as badge gape wrath pun cloth sick love rough kept calf
Greek beck nigh flop roe thick best fall choose flap jag frock chop
wasp true cheat tongue ode pass wink hitch hull browse zone kill
bag fee punt odds rooms lag shove kid fowl thigh hill trade bind
reap chart black scare writ wait high mast wife cob rind fling rot
pipe clothes mash vase good gage eyes rode lend forge raise sniff
puff yawn prime deep inch watch scan shank bronze thud grope
ray solve tug sup gap bathe curse slouch crib add owls thus clad
pus rear nose prig eat shine grudge flick dad gasp by wheeze
bored woo am roll slide though nine look ease act wire freak
queen dwarf aim spice jell scout shaft hum forth sledge south woo

Figure 3. Visual Free Time Task

The card was bordered in black and had a white background with black letters. The card was sprayed with a glare reducing compound and mounted on the UH-1H instrument panel directly below the vertical velocity indicator. The average distance from the subject's eyes to the visual free time task card was 87 centimeters (reference Table 1 for cockpit measurement data).

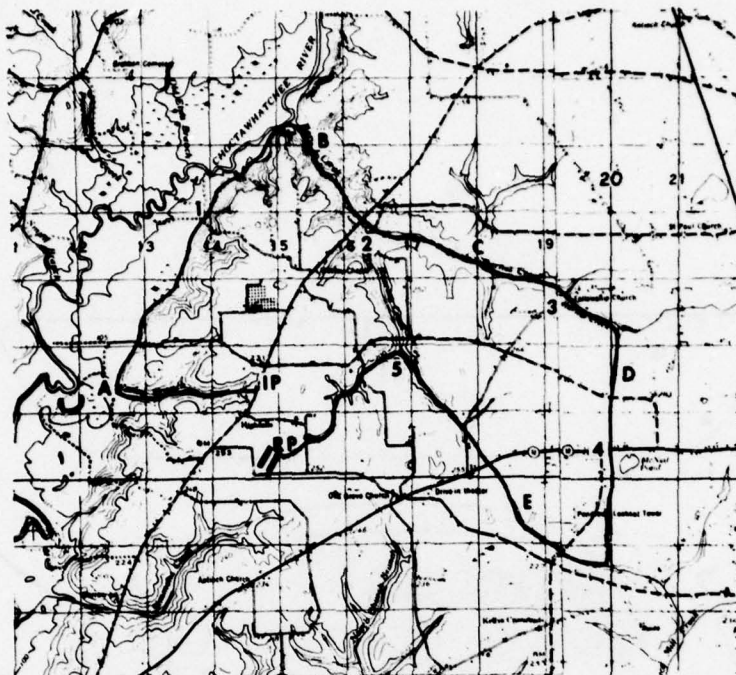
TABLE 1
COCKPIT MEASUREMENT DATA

	<u>Eye to Floor</u>	<u>Eye to Magnetic Comp.</u>	<u>Eye to VFT Task</u>
Subject One	101.60	68.58	86.36
Subject Two	107.95	81.28	88.90
Subject Three	106.68	71.12	88.90
Subject Four	108.59	76.20	91.44
Subject Five	104.14	76.20	83.82
Subject Six	109.22	85.09	93.98
Subject Seven	100.33	73.66	83.82
Subject Eight	113.03	83.82	88.90
Subject Nine	107.95	82.55	86.36
Subject Ten	110.49	77.47	95.25
Mean	106.99	77.59	88.77

*Unit of measurement - centimeters.

The maps utilized were standard 1:50,000 scale, with white background, of the Geneva (Stock No. V744X38463) and Hartford (Stock No. V744X38462), Alabama, area. A map encompassing a 255 square kilometer test area around the Highfalls Stagefield was prepared for use by the participants.

The navigation course, approximately 19 kilometers long, was marked on the map (reference Figure 4). The participants were given six digit grid coordinates of five phase points/checkpoints plus the initial point (IP) of the navigation course. These points were to be identified on the map by the subject during his map study and reported upon passage during flight over the course. The subjects were also given a list containing six digit grid coordinates of five hover points located along the navigation course. These points were utilized to represent landing points, such as equipment or personnel pick up points, in an operational setting.



NAVIGATION COURSE _____ SCALE 1:50,000
 IP-INITIAL POINT CONTOUR INTERVAL-20 FEET
 RP-RELEASE POINT 1,2,3,4,5-CHECK POINTS
 A,B,C,D,E-HOVER POINTS

Figure 4. Navigation Course Utilized in the Investigation

Procedure. The participants were first given a briefing concerning the general nature of the research and their role in the project. The subjects were provided the map similar to the one shown in Figure 4 (excluding the location of the checkpoints and hover points) and the list of phase/checkpoints and hover points. The participants were told that they were to act as navigator or copilot and that a USAARL pilot would act as first pilot or aircraft commander during the flight. The participants were able to perform a map study for the rest of that day and reported to the aircraft the next day prepared to fly.

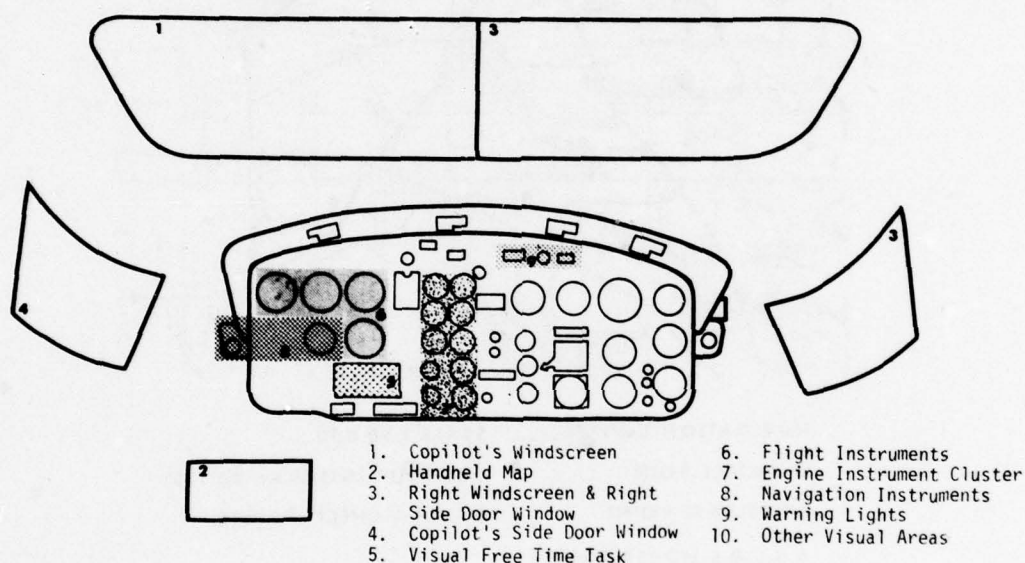


Figure 5. Schematic of UH-1 Visual Areas

Tables 2 through 7 show the summary of the visual data for each of the segments in the navigation course for all subjects whose data were scorable. Segments of data were lost on some subjects as a function of camera malfunctions and film exposure problems due to the fact that the NAC Eye Mark Recorder system does not have an automatic T-stop adjustment capability. However, the data remaining accurately reflect the visual performance exhibited during navigation.

Some of the key items of interest in Tables 2 through 7 are the mean dwell time figures representing the average period of visual contact with the area and percentage of total time of the segment spent in each of the visual areas.

Immediately before flight, the subjects were again informed that they were to act as copilot/navigator and to perform all duties associated with that position. The UH-1H Tactics Flight Training Guide (March 1975), which identifies the pilot and copilot's in-flight duties, was given to the subjects to refresh their memory as to the exact functions expected of them during the flight.¹ The participants were told that their responsibility for the flight was to direct the pilot to fly along the course identified on the maps provided. They were responsible for keeping the pilot informed so that he could fly the aircraft as close to the course as possible.

The following VFT task instructions, which are similar to the Strother study,⁶ were also given to the subjects: "During the course of the flight, when you feel that it is not necessary to look inside or outside the helicopter in performance of your navigation duties, read the words located on the card mounted on the instrument panel. Start reading at any word and it is not necessary to pick up where you stopped before. Read aloud as many words as you feel you have time for and then stop reading and return to your normal duties."

The NAC Eye Mark Recorder was fitted and calibrated on the subject inside the USAARL research facility followed by a recalibration of the device after the subject was seated and prepared for flight in the left front seat of the UH-1H aircraft. From takeoff to completion of the course, subjects were completely responsible for the flight path of the helicopter with the USAARL pilot changing heading, airspeed and altitude in response to their directions. The subjects were instructed to report the passage of the five phase/checkpoints. Subjects were also responsible for identifying the five hover points and directing the pilots to hover at these points.

RESULTS AND DISCUSSION

For scoring purposes, the visual performance data were divided into ten visual areas of interest. These areas are schematically presented in Figure 5. The copilot's instrument panel was divided into functional groups of instruments, e.g., navigation instruments (the RMI and magnetic compass) engine instruments, etc. The copilot's windscreen was originally divided into four quadrants, but these areas were consolidated into one visual area for data interpretation purposes.

TABLE 2
VISUAL PERFORMANCE SUMMARY DATA FOR
SEGMENT ONE OF THE NAVIGATION COURSE
IP TO HOVER POINT A

<u>Visual Area</u>	<u>Total Time in Seconds</u>	<u>Percent of Total Time</u>	<u>Total Number of Exits/Min.</u>	<u>Mean Time in Area</u>
Copilot's Windscreen	792.28	52.4	14.04	2.23
Handheld Map	424.81	28.1	10.26	1.63
Right Windscreen & Right Side Door Window	110.19	7.3	3.48	1.24
Copilot's Side Door Window	106.21	7.0	2.58	1.61
Visual Free Time Task	14.06	.9	0.24	2.01
Flight Instruments	18.72	1.2	0.72	0.99
Engine Instrument Cluster	11.61	.7	0.54	0.77
Navigation Instruments	15.61	1.0	0.90	0.65
Warning Lights	9.31	.6	0.30	1.03
Other Visual Areas	10.33	.6	0.36	1.03

TABLE 3
VISUAL PERFORMANCE SUMMARY DATA FOR
SEGMENT TWO OF THE NAVIGATION COURSE
HOVER POINT A TO HOVER POINT B

<u>Visual Area</u>	<u>Total Time in Seconds</u>	<u>Percent of Total Time</u>	<u>Total Number of Exits/Min.</u>	<u>Mean Time in Area</u>
Copilot's Windscreen	1073.38	49.0	12.96	2.27
Handheld Map	752.04	34.4	11.16	1.84
Right Windscreen & Right Side Door Window	103.54	4.7	2.58	1.07
Copilot's Side Door Window	87.57	4.0	1.68	1.41
Visual Free Time Task	42.95	1.9	0.24	4.29
Flight Instruments	64.95	2.9	0.36	1.38
Engine Instrument Cluster	37.90	1.7	0.72	1.40
Navigation Instruments	11.41	.5	0.36	0.81
Warning Lights	4.82	.2	0.12	0.96
Other Visual Areas	4.52	.2	0.18	0.56

TABLE 4
VISUAL PERFORMANCE SUMMARY DATA FOR
SEGMENT THREE OF THE NAVIGATION COURSE
HOVER POINT B TO HOVER POINT C

<u>Visual Area</u>	<u>Total Time in Seconds</u>	<u>Percent of Total Time</u>	<u>Total Number of Exits/Min.</u>	<u>Mean Time in Area</u>
Copilot's Windscreen	396.31	43.6	12.00	2.18
Handheld Map	302.51	33.2	9.36	2.13
Right Windscreen & Right Side Door Window	24.13	2.6	1.86	0.83
Copilot's Side Door Window	96.62	10.6	4.02	1.58
Visual Free Time Task	30.29	3.3	0.36	5.04
Flight Instruments	27.96	3.0	0.72	2.54
Engine Instrument Cluster	3.20	.3	0.30	0.64
Navigation Instruments	5.83	.6	0.48	0.72
Warning Lights	17.05	1.8	0.42	2.43
Other Visual Areas	4.56	.5	0.00	0.31

TABLE 5
VISUAL PERFORMANCE SUMMARY DATA FOR
SEGMENT FOUR OF THE NAVIGATION COURSE
HOVER POINT C TO HOVER POINT D

<u>Visual Area</u>	<u>Total Time in Seconds</u>	<u>Percent of Total Time</u>	<u>Total Number of Exits/Min.</u>	<u>Mean Time in Area</u>
Copilot's Windscreen	798.08	45.2	11.40	2.38
Handheld Map	656.30	37.2	9.90	2.25
Right Windscreen & Right Side Door Window	74.97	4.2	2.10	1.19
Copilot's Side Door Window	77.03	4.3	1.62	1.60
Visual Free Time Task	87.47	4.9	0.40	7.28
Flight Instruments	18.46	1.0	0.60	1.02
Engine Instrument Cluster	19.87	1.1	0.54	1.24
Navigation Instruments	11.31	.6	0.48	0.75
Warning Lights	1.91	.1	0.10	0.63
Other Visual Areas	16.44	.9	0.48	1.09

TABLE 6

VISUAL PERFORMANCE SUMMARY DATA FOR
SEGMENT FIVE OF THE NAVIGATION COURSE
HOVER POINT D TO HOVER POINT E

<u>Visual Area</u>	<u>Total Time in Seconds</u>	<u>Percent of Total Time</u>	<u>Total Number of Exits/Min.</u>	<u>Mean Time in Area</u>
Copilot's Windscreen	803.22	44.9	13.50	1.99
Handheld Map	659.28	36.8	10.98	2.00
Right Windscreen & Right Side Door Window	94.66	5.2	3.06	1.02
Copilot's Side Door Window	42.88	2.3	1.02	1.38
Visual Free Time Task	67.83	3.7	0.63	3.57
Flight Instruments	37.95	2.1	1.02	1.22
Engine Instrument Cluster	38.10	2.1	1.20	1.02
Navigation Instruments	24.54	1.3	0.90	0.87
Warning Lights	10.08	.5	0.18	1.68
Other Visual Areas	10.25	.5	0.42	0.78

TABLE 7

VISUAL PERFORMANCE SUMMARY DATA FOR
SEGMENT SIX OF THE NAVIGATION COURSE
HOVER POINT E TO HIGHFALLS STAGEFIELD (RP)

<u>Visual Area</u>	<u>Total Time in Seconds</u>	<u>Percent of Total Time</u>	<u>Total Number of Exits/Min.</u>	<u>Mean Time in Area</u>
Copilot's Windscreen	882.15	44.5	13.44	1.98
Handheld Map	753.68	38.0	11.22	2.03
Right Windscreen & Right Side Door Window	95.74	4.8	3.24	0.88
Copilot's Side Door Window	62.37	3.1	1.68	1.11
Visual Free Time Task	65.95	3.3	0.72	2.74
Flight Instruments	19.89	1.0	0.60	0.99
Engine Instrument Cluster	59.53	3.0	1.02	1.70
Navigation Instruments	11.06	.5	0.42	0.73
Warning Lights	6.96	.3	0.30	0.63
Other Visual Areas	21.90	1.1	0.54	1.21

Figure 6 provides summary data for all six flight segments in terms of the percentage of total visual time spent in each of the ten visual areas. The shaded area includes all mean data points for each of the six flight segments. The consistency between flight segments is particularly noteworthy. These data indicate very little variability in percent of time each of the visual areas was utilized over the entire navigation course. Though the terrain traversed did vary to some degree over the course, the information demanded from each of the visual areas remained relatively constant. That is, visual cues needed for navigation were primarily obtained from terrain viewed through the copilot's windscreen with frequent reference to the handheld map.

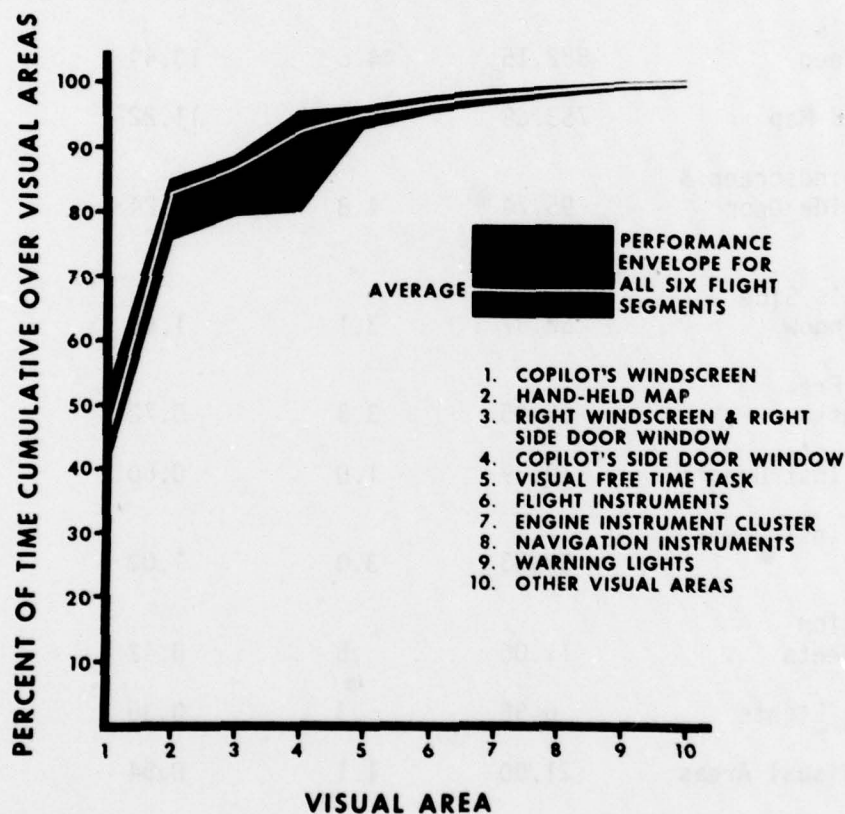


Figure 6. Percentage of Time Across Visual Areas

It is noteworthy that the visual cues necessary for navigation were evidently present primarily in the area viewed through the copilot's windscreen. This fact is pointed out in the data presented in Figure 6 and Table 8 which contains the summary data for all six flight segments combined.

TABLE 8
VISUAL PERFORMANCE SUMMARY DATA
REPRESENTING ALL SIX FLIGHT SEGMENTS

Visual Area	Total Time in Seconds	Percent of Total Time	Total Number of Exits/Min.	Mean Time in Area
Copilot's Windscreen	4744.35	46.8	12.82	2.191
Handheld Map	3540.60	34.9	10.64	1.197
Right Windscreen & Right Side Door Window	508.20	5.0	2.81	1.069
Copilot's Side Door Window	472.85	4.7	1.96	1.428
Visual Free Time Task	308.66	3.0	0.44	4.115
Flight Instruments	187.95	1.8	0.91	1.212
Engine Instrument Cluster	170.16	1.7	0.78	1.289
Navigation Instruments	79.80	.8	0.58	0.806
Warning Lights	50.16	.5	0.24	1.223
Other Visual Areas	68.50	.7	0.40	1.007

The navigators spent 46.8% of the total visual time during the flight obtaining information through the left windscreen compared to: (1) 5% of the time viewing the terrain through the right windscreen and right door window, and (2) 4.9% of the time searching for navigation information through the left door window.

The magnitude of the demand for visual information can be seen in Figure 7, which reflects summary data for all six flight segments combined in terms of the number of exits per minute for each of the visual areas.

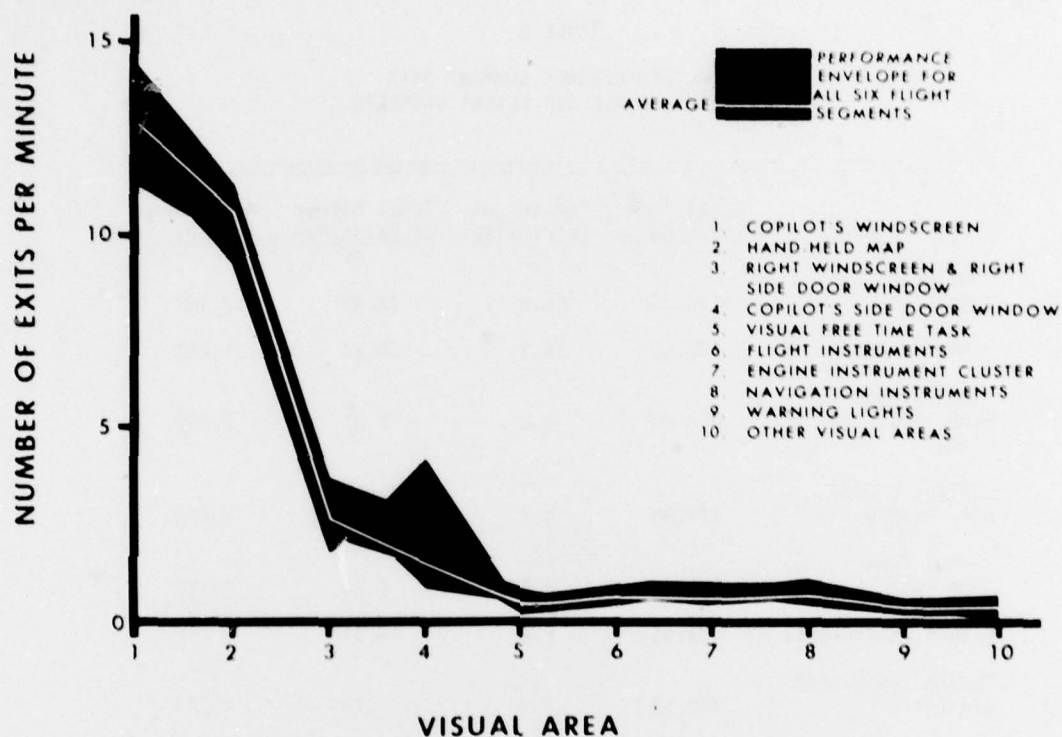


Figure 7. Exits Per Minute Across Visual Areas

Interpretation of these data should be made in light of Senders' statement that the frequency of eye fixations in a visual area reflects the relative importance of that area. Thus, two areas, copilot's windscreen and the handheld map, far outweigh all others in terms of frequency of demand of visual information. These data point to the copilot's primary duty of navigating and seeking information in the terrain which corresponds to that depicted on the map. Following these two high visual use areas are two other windscreen or window areas; right windscreen and right side door window, and copilot's left side window. The percentage of time in each visual area also shows the same order of utilization: (1) copilot's windscreen, (2) handheld map, (3) right windscreen and right side door window, and (4) copilot's left side door window. Again, the

total visual contact for these areas, for all flight segments, (reference Table 8) represents 91.4% of the time in flight. More specifically, 56.5% of the time was used by the aviators to obtain navigation cues from outside the cockpit and an additional 34.9% of the flight time was spent obtaining information from the handheld map.

Traditionally, heading reference obtained from the RMI and magnetic compass has been critical for successful navigation at higher altitudes. However, the summary data (reference Table 8 and Figures 6, 7 and 8), indicate that the magnetic compass and RMI are used very infrequently and for the shortest mean dwell time.

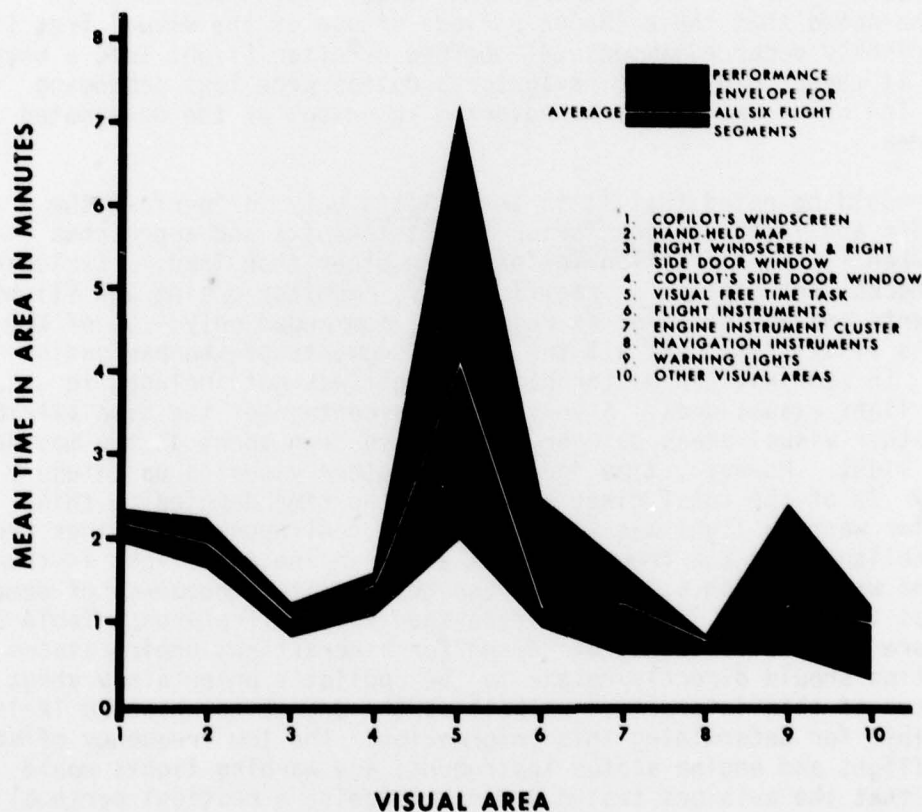


Figure 8. Mean Time in Each Visual Area

When the percentage of time the RMI and magnetic compass were used is added to the previously mentioned time spent outside the cockpit and time spent on the map, a total of 92.2% of the visual time is accounted for by the performance of the basic duty of navigation.

Three primary facets of Figure 8 should be discussed. The first concerns the fact that the five visual areas primarily used for navigation (areas 1, 2, 3, 4, 8) reflect very little variability in mean time or dwell time across each of the six course segments. The low frequency of use of visual areas such as 5, 6, 7, and 9, show much larger variability in mean dwell time in each area across the six course segments. The largest variation can be observed on the visual free time task (area 5) which reflects mean dwell time ranging from 2.01 seconds to 7.28 seconds. These data seem to indicate that the subject aviators attempted to compensate for their infrequent use of the visual free time task by reading as long as possible during noncritical flight periods. It should be noted that these longer periods of use of the visual free time task typically occurred immediately before or after flight into a hover point. At these points, the navigator's duties were less demanding because the pilot was simply maneuvering in or out of the designated hover area.

It should be noted that it is the pilot's duty to "perform the pretakeoff and landing checks prior to all takeoffs and approaches except when flying a position in formation other than lead." Excluding these checks, the copilot's specified duty, "monitor engine and flight instruments and advise pilot as required," commanded only 4.0% of the copilot's visual time over all the flight segments of the navigation course. In scoring, the master caution light was not included in warning light visual area. A very small percentage of the time attributed to the other visual areas category could have been spent on the master caution light. However, time spent in the other visual area category was only .7% of the total time; therefore, the time devoted to this particular warning light was inconsequential. Although guidelines are not established for the frequency of scan of engine and flight instruments and warning lights, one would assume a greater frequency of demand of visual information from these areas than existed (reference Table 8 and Figure 7). The frequency of demand for aircraft and engine status information should directly relate to the copilot's uncertainty about the status of this information as well as the degree to which he feels responsible for determining this information. The low frequency of scan of the flight and engine status instruments and warning lights would suggest that the aviators tested did not perceive a critical personal need for this information.

Link values or the number of transitions from each of the visual areas to all other areas indicate the copilot's information seeking behavior. The link values reported in Table 9 are supportive of the previous data in that the primary transitions are between the copilot's windscreen and the handheld map.

The primary act of navigation in a rotary wing NOE, low level or contour environment could be described as a feature or pattern comparison between the map and the terrain in sight. However, before the pattern matching can occur, the navigator must first perform a search task for critical geographical features. Navigation requires the constant integration of information deemed critical on the map and comparing this array of features to the actual terrain. The navigator's task is made more difficult by the fact that he must (1) view the terrain in a variety of states, e.g., seasonal changes, visibility or illumination differences, day and night; and (2) compensate for the discrepancies between the map and the terrain in areas where significant terrain features have been changed, e.g., fields cleared, roads and bridges added, etc.

In conclusion, the data from this study will provide baseline information for comparison with the performance of other aircrew duties or missions. As well, it is very important to note objectively the copilot's priorities in carrying out his primary and secondary subtasks. The imbalance in the copilot's distribution of visual time across subtasks indicates that: (1) new maps should be developed that will allow the navigator to reduce his information processing and search time, and (2) new navigation aids should be developed that will provide information which will reduce the navigator's time on navigation tasks. Data from this study indicate that unless these developments are added to the flight inventory, the copilot will have a very limited opportunity to perform other in-flight tasks such as target detection and identification. As well, flight safety is currently compromised because of the copilot's inability to attend to critical engine status instruments.

TABLE 9
LINK VALUES BETWEEN VISUAL AREAS
TOTALLED ACROSS ALL SIX FLIGHT SEGMENTS

	1	2	3	4	5	6	7	8	9	10	Total
	Copilot's Windscreen	Hand-Held Map	Right Windscreen & Right Side Door Window	Copilot's Left Side Door Window	Visual Free Time Task	Flight Instruments	Engine Instrument Cluster	Navigation Instruments	Warning Lights	Other Visual Areas	
1 Copilot's Windscreen		1440	331	198	30	58	55	28	7	16	2163
2 Hand-Held Map	1463		108	110	12	43	17	27	9	9	1798
3 Right Windscreen & Right Side Door Window	253	165		12	2	3	9	4	6	22	476
4 Copilot's Left Side Door Window	207	106	1			2	3		1	2	322
5 Visual Free Time Task	38	11	5			7	9	7	1	1	79
6 Flight Instruments	66	22	4	4	7		13	28	1	1	146
7 Engine Instru- ment Cluster	58	21	2	7	14	13		4	15	10	144
8 Navigation Instruments	47	17	4		5	24	1		1	2	101
9 Warning Lights	12	2	2		2	2	14			5	39
10 Other Visual Areas	21	13	18		3	3	11	1			70
Total	2165	1797	475	331	75	155	132	99	41	68	

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Mark A. Hornam, 32 pp., Aviation Psychology Division,
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The emphasis on aviator workload has been of primary concern to the U.S. Army aviation community since the incorporation of low altitude terrain flight techniques into the helicopter tactics repertory. Since navigation is a particularly acute problem at low altitudes, this project examined the visual workload of the navigator/copilot during terrain flight (nap-of-the-earth, contour and low level) in a UH-1H helicopter. The navigator's task was to: (1) perform a map study of the prescribed course, (2) direct the pilot during the flight as to the direction of flight, altitude and airspeed desired to traverse the course, and (3) identify hover points and checkpoints along the route which were given to the navigator in terms of six digit grid coordinates. Visual performance was measured via a modified MAC Eye Mark Recorder used in conjunction with a LOCAM high speed camera. This technique provided the means to objectively record and analyze the navigator's visual performance through the examination of: (1) visual time inside the cockpit on flight and engine instruments, (2) time inside the cockpit on the map or other navigation aids, and (3) time outside the cockpit in various windscreen sectors.

A visual free time task was utilized to determine the amount of visual time the navigator had available during flight over the prescribed course, for a nonflight related task. The data indicate that the navigator's normal workload was demanding; the visual free time task was utilized only 3% of the total time. The data also indicate that the duty of navigating required 92.2% of the copilot's total visual time while the engine and flight instruments were utilized only 4% of the time. These data are discussed in relation to the copilot's specified duties.

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