VISUAL PERFORMANCE/WORKLOAD OF HELICOPTER PILOTS DURING INSTRUMENT FLIGHT.

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Pilot Performance
Visual Workload
Rotary Wing Aircraft
Instrument Flight
Helicopter In-Flight Monitoring System

Flight under instrument flight rules (IFR) is reported to be one of the most important factors contributing to aviator fatigue during helicopter operations. This study was initiated to collect visual and psychomotor performance data in an attempt to investigate and study the general visual performance of aviators during IFR conditions. Two groups of aviators, with varied experience levels, were the subjects.
A NAC Eye Mark Recorder and the Helicopter In-Flight Monitoring System were utilized to collect the required data. The results indicated, among other findings, that pilot subjective opinion does not agree with objective data. Additionally, the attitude indicator and radio compass comprised over 60% of the pilots' total visual workload, while the aircraft's status gauges were monitored less than 10% of the total time. These data should provide invaluable information concerning the visual requirements of pilots for safe helicopter operations.
SUMMARY

Flight under instrument flight rules (IFR) is reported to be one of the most important factors contributing to aviator fatigue during helicopter operations. This study was initiated to collect visual and psychomotor performance data in an attempt to investigate and study the general visual performance of aviators during IFR conditions. Two groups of aviators, with varied experience levels, were the subjects.

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STANLEY C. KNAPP
Colonel, MC
Commanding
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INTRODUCTION

The airmobility concept can be defined as the utilization of aerial vehicles organic to the Army to assure the balance of mobility, firepower, intelligence, support, and command and control. The aerial vehicle which has proven to best provide the support for this concept has been the helicopter. Army aircrews, utilizing the helicopter to support the ground fighting forces with rapid transportation, supplies, and medical evacuation, fly under any and all weather conditions. To accomplish these missions, Army aviators are required to fly through meteorological conditions during which they are unable to identify any outside references to aid in the control of their aircraft. This necessitates that they receive all visual cues from cockpit instruments which artificially represent their aircraft's relative spatial and geographical position. This type of flight, which is performed utilizing instruments to fly the aircraft, is referred to as flight under instrument flight rules (IFR).

This IFR flight condition has been referred to in AGARD Advisory Report No. 69 as being the most important contributing factor to aviator fatigue during helicopter operations with a possible exception of nap-of-the-earth flight. Additionally, in light of the reported accidents during IFR flights or reduced visibility conditions, it can be concluded that either relevant perceptual cues which exist outside the cockpit are not adequately represented within the cockpit or the information is present but cannot be used effectively. It must be pointed out that optimal rotary wing flight during IFR and reduced visibility conditions is not likely to be achieved by merely representing the outside world in the cockpit via an instrument display. The basic questions of what cues are required for safe flight and how to correctly display them must still be answered.

Several studies have been devised to collect data related to visual performance. These investigations can be divided into three categories: (1) subjective opinions of visual performance, (2) objective visual performance data during fixed wing flight, and (3) objective data during helicopter flight. Studies by Siegel and MacPherson, Clark and Intano, Simmons, et al, have analyzed the opinions of aviators as to which instruments they felt were utilized to fly selected maneuvers. However, these findings do not agree with research results of Frezell, et al; Sanders; and Simmons, et al. These investigators have reported a very poor agreement between subjective data and actual pilot visual performance. Additional studies by Milton, Jones, and Fitts; Fitts, et al; and Diamond have utilized test equipment to obtain objective visual performance data of aviators during flight maneuvers in
several fixed wing aircraft. Although these investigations provided useful information as to visual performance during fixed wing flight, data obtained during this work cannot be easily generalized to rotary wing flight because of the extreme aerodynamic differences between airplanes and helicopters.

Sunkes, et al; Stern and Bynum; Frezell, et al, have recorded visual performance in helicopters during selected visual flight rules (VFR) flights. Additionally, two reports investigated a number of maneuvers utilizing both the interview technique as well as in-flight recordings of visual performance of two aviators during IFR. These efforts have provided some needed information as to the frequency, duration, and sequence of fixations during helicopter operations. Although all of these studies have provided useful information for the visual performance data base, much investigation remains to be accomplished before a reliable visual performance/workload model can be established for safe helicopter flight.

The purpose of this investigation was to measure the visual performance of helicopter pilots during IFR conditions in an attempt to provide a data base which would not only answer some of the basic questions about visual workload during instrument flight, but would also provide a means of comparing simulated IFR, VFR, night, and nap-of-the-earth flights in helicopters with respect to their varying visual performances and workloads. This information will be invaluable when applied to the development of more efficient training techniques, procedures, and aircraft instrumentation in that a significant reduction in the overall visual performance/workload of the aviator during helicopter operations will be realized.
METHOD

Subjects: Subjects for this investigation were selected from a group of volunteer pilots stationed at Fort Rucker, Alabama. For design purposes subjects were assigned to two general groups of aviators. The first group consisted of five rated helicopter aviators who had no visual problems which would be incompatible with the NAC Eye Mark system, possessed an Army standard instrument rating, were currently on flight status, and had logged less than 250 hours of flight time. For comparisons to past reports this group was designated as student qualified aviators (SQA).

The second group of five subjects possessed the same qualifications as the first with the exception that they had logged over 2400 hours of flight time and were instrument instructor pilots. Again, for comparative reasons, this group was referred to as instrument qualified aviators (IQA). Biographical information for the two groups is presented in Table 1.

TABLE 1
BIOGRAPHICAL SKETCH OF SUBJECTS

<table>
<thead>
<tr>
<th></th>
<th>SQA¹</th>
<th>IQA²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21-29/24.6</td>
<td>27-33/29.60</td>
</tr>
<tr>
<td>Years Service</td>
<td>1-4.5/2.6</td>
<td>6-11/7.80</td>
</tr>
<tr>
<td>Total Flight Time/Mean</td>
<td>208.28</td>
<td>2452.0</td>
</tr>
<tr>
<td>Total Instrument &amp; Hood/</td>
<td>30-50/41.16</td>
<td>100-200/141</td>
</tr>
<tr>
<td>Hood Last 6 Months/Mean</td>
<td>20-45.8/36.16</td>
<td>12-50/36.6</td>
</tr>
</tbody>
</table>

¹ Student Qualified Aviators
² Instrument Qualified Aviators
Equipment: Equipment utilized to record visual performance included a NAC Eye Mark Recorder, a LOCAM high speed motion picture camera, and Kodak 4X negative black and white film (ASA 500/400 ft. X 16mm). Flight and psychomotor data were obtained through the use of the Helicopter In-Flight Monitoring System (HIMS).

NAC Eye Mark Recorder: The basic device employed to study visual performance/workload was the NAC Eye Mark Recorder which utilizes the corneal reflection technique. Through the application of this technique, foveal fixation points as well as other oculomotor behavior can be detected and recorded. An illuminated reticle is focused on the cornea and reflected by the mirrors on the NAC such that the reticle is superimposed on the pilot's actual field of view. The pilot's eye movement and fixation points are then recorded on 16mm film. A static illustration of the NAC is provided in Figure 1.
The complete description, specifications, and operating procedures for the NAC system are outlined in USAARL Report No. 77-4.

**Camera System:** The camera arrangement consisted of a LOCAM Model 51-0002 high speed motion picture camera with decoder and time code generator. The NAC/camera arrangement is illustrated in Figure 2.
The LOCAM camera with decoder is located to the far left of the picture. The recording adapter and optic bundle link the NAC mask to the camera. Directly behind the camera is a 30 Vdc battery which provides power for the time code generator located to the right of the NAC. The smallest box is a variable power supply which was designed and fabricated by the laboratory to provide a constant power supply for the reticle light of the NAC.

Helicopter In-Flight Monitoring System (HIMS): The HIMS (Figure 3) provided real time acquisition of all major motion and control parameters. The HIMS monitored and recorded aircraft movements in six
degrees of freedom as well as all pilot control movements on the cyclic, collective, pedals, and throttle. Measures of rates and accelerations along each axis were also obtained. A more complete description of this system is available in USAARL No. 72-11.16

Aircraft (JUH-1H): Subjects for this investigation flew in an Army JUH-1H helicopter modified to provide inputs to the HIMS. The aircraft was dual instrumented with the pilot's panel arrangement being standard with the exception of an AAU-32/A Altitude Encoder/Pneumatic altimeter. Figure 4 provides a schematic representation of the UH-1 instrument panel.

![UH-1H Instrument Layout](image)
PROCEDURES

**Initial Briefing:** The selected subject pilots initially visited the laboratory and were interviewed. During these sessions, subjects were fitted with the NAC mask, briefed about their general responsibilities during the study, and scheduled for the research flight to be initiated from Cairns Army Airfield, Fort Rucker, Alabama.

**In-Flight Investigation:** On the designated date each subject met the research team at the USAARL Aviation Section at Cairns AAF. During this time the subject pilot was briefed. He was to be the pilot in command during an instrument flight which would be initiated from Runway 36, where the pilot was to perform an instrument takeoff, track in-bound to the Enterprise nondirectional beacon, perform some basic IFR flight maneuvers at the command of the safety pilot, and finally perform an ILS approach to Runway 06 at Cairns. After this briefing the subject was fitted with the NAC and the system was calibrated. The subject then proceeded to the aircraft where he was seated and the normal safety procedures of fastening restraints and checking communications were accomplished. The NAC system was connected to the camera system and fine adjustment of the NAC performed.

Before starting the test profile, the helicopter was hovered from three to five minutes to allow the NAC time to settle on the subject's head. This time was utilized to move the aircraft from its parking location to the taxiway short of the designated runway. The NAC was adjusted for the final time and the camera turned on.

The profile, as described, consisted of requiring the subject pilot to fly under instrument conditions toward the Enterprise nondirectional beacon. During this enroute phase, the subject was to perform, on command, a variety of basic instrument flight maneuvers to include level flight, climbs, turns, climbing turns, descending turns, and straight descents. For purposes of this investigation, these maneuvers are defined in Table 2. Figure 5 demonstrates the mission profile. Average time for these research flights was 30 minutes. Because of the limitation of film capacity, cameras were changed about midway through the profile and calibration of the NAC was checked. This calibration check was again performed after the completion of the profile.
TABLE 2

FLIGHT MANEUVERS IN THE UH-1 (IFR)

Instrument Takeoff (ITO) - Is defined from complete stop on the active runway through lift off to 450 ft., maintaining runway heading.

Climb - Is defined as straight ascent of at least 1000 ft. maintaining a constant heading with standard school procedures (+10 knots airspeed and 500 FPM). No separate navigation task was assigned.

Cruise - Is defined in this study as level flight for at least one minute, maintaining standard school procedures with no additional task assigned other than maintaining constant heading.

Descent - Is defined as the intentional loss of altitude of at least 1000 ft., maintaining a constant heading following school procedures with no additional task assigned.

Climbing Turn - Was performed by simultaneously changing direction of 180 degrees and climbing 500 ft. No other task assigned.

Descending Turn - Was the simultaneous descending and turning 500 ft. at 180 degrees. No other task assigned.

Level Turn - Was performed by banking the aircraft and turning while maintaining constant altitude and airspeed. No other task assigned.

Instrument Landing (ILS) - Is defined in this study as the published ILS approach RWY6 to Cairns Army Airfield. The maneuver began at Cairns outer marker (OM) and ended at Cairns middle marker (MM). This maneuver differed from all other maneuvers in that the additional task of monitoring the OBS gauge was required.

After mission termination the subject was debriefed and given a short questionnaire which requested his impressions of his visual performance during the various maneuvers. An example of the questionnaire is provided in Appendix A.
Measurements: Continuous information was recorded pertaining to the ten subject pilots' visual and psychomotor performance as well as the status and control response of the aircraft. Oculomotor behavior was collected at 16 data points per second. Twelve areas were selected which best described the pilots' visual performance. A thirteenth area was labeled "all other areas." If the percentage of time spent monitoring this area was significantly low it could be assumed that the other twelve areas accurately represented the total visual performance of the subjects. A list of these areas is presented in Table 3.
TABLE 3
THIRTEEN VISUAL DATA POINTS

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<tr>
<td>1</td>
<td>REST  All other areas not included in the following twelve areas:</td>
</tr>
<tr>
<td>2</td>
<td>ALT   AAU-32/A Altitude Encoder/Pneumatic Altimeter</td>
</tr>
<tr>
<td>3</td>
<td>VSI   Standard UH-l Vertical Velocity Indicator</td>
</tr>
<tr>
<td>4</td>
<td>OBS   Standard UH-l Omni Indicator</td>
</tr>
<tr>
<td>5</td>
<td>T&amp;B   Standard UH-l Turn and Slip Indicator</td>
</tr>
<tr>
<td>6</td>
<td>RMI   Standard UH-l Radio Magnetic Compass</td>
</tr>
<tr>
<td>7</td>
<td>AH    Standard UH-l Pilot's Attitude Indicator</td>
</tr>
<tr>
<td>8</td>
<td>AS    Standard UH-l Airspeed Indicator</td>
</tr>
<tr>
<td>9</td>
<td>TORQ  Series of instruments including the Torquemeter, Gas Producer Tachometer, and Exhaust Gas Temperature Indicator</td>
</tr>
<tr>
<td>10</td>
<td>RPM   Dual Rotor and Engine Tachometer</td>
</tr>
<tr>
<td>11</td>
<td>ELEC  The electrical gauges which include AC and DC Voltmeters and the main and standby Generator Loadmeters.</td>
</tr>
<tr>
<td>12</td>
<td>OIL   The oil monitoring gauges to include Engine and Transmission Oil Temperature and Pressure gauges.</td>
</tr>
<tr>
<td>13</td>
<td>FUEL  The Fuel Pressure and Fuel Quantity gauges</td>
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Twenty data points per second were recorded from eighteen pilot and aircraft parameters via HIMS. These pilot and aircraft parameters were mainly utilized to judge the quality of each flight. Those utilized for this work are listed in Table 4.
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<th>MEASURE</th>
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<td>-Standard Deviation</td>
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<tr>
<td></td>
<td>-Movement Per Second</td>
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<tr>
<td></td>
<td>-Percent of Steady State</td>
</tr>
<tr>
<td>2. Left/Right Cyclic</td>
<td>-Standard Deviation</td>
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<tr>
<td></td>
<td>-Movement Per Second</td>
</tr>
<tr>
<td></td>
<td>-Percent of Steady State</td>
</tr>
<tr>
<td>3. Collective</td>
<td>-Standard Deviation</td>
</tr>
<tr>
<td></td>
<td>-Movement Per Second</td>
</tr>
<tr>
<td></td>
<td>-Percent of Steady State</td>
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<tr>
<td>4. Pedals</td>
<td>-Standard Deviation</td>
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<td></td>
<td>-Movement Per Second</td>
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<td></td>
<td>-Percent of Steady State</td>
</tr>
<tr>
<td>5. Pitch</td>
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<tr>
<td>6. Turn Rate</td>
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<tr>
<td>7. Climb Rate</td>
<td>-Standard Deviation</td>
</tr>
<tr>
<td>8. Heading</td>
<td>-Standard Deviation</td>
</tr>
<tr>
<td>9. Altitude</td>
<td>-Standard Deviation</td>
</tr>
<tr>
<td>10. Airspeed</td>
<td>-Standard Deviation</td>
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</table>
ANALYSIS AND RESULTS

Visual Performance: Visual Performance was analyzed for each of the eight maneuvers described in Table 2. Reduction of the film data provided seconds per maneuver that fixations were recorded within each of the thirteen areas described in Table 3. In addition, the number of fixations per area and the first generation link values for each of these areas were recorded. From these values, the percentage of time spent within each area per maneuver was computed as well as mean dwell time and scan rate per minute for each area. The definitions and formulas utilized for these measures are found in Table 5.

TABLE 5
DESCRIPTION OF BASIC AND DERIVED VISUAL MEASURES

<table>
<thead>
<tr>
<th>UNIT</th>
<th>DEFINITION</th>
<th>SYMBOL/FORMULA</th>
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<tbody>
<tr>
<td>1. Fixation</td>
<td>The stationary eye movement within a designated area for at least 100 milliseconds</td>
<td>F</td>
</tr>
<tr>
<td>2. Number</td>
<td>The sum of fixations on a designated area (instrument)</td>
<td>N</td>
</tr>
<tr>
<td>3. Time</td>
<td>The sum of time spent fixated on a designated area (instrument)</td>
<td>T</td>
</tr>
<tr>
<td>4. Link Values</td>
<td>The visual path traveled from one area (instrument) to another</td>
<td>LV</td>
</tr>
<tr>
<td>5. Dwell Time</td>
<td>Mean time fixated per area</td>
<td>DT = T/N</td>
</tr>
<tr>
<td>6. Percent of Time</td>
<td>The percentage of lapse time during a maneuver which was allotted to each area</td>
<td>%T = T/ Σ T X 100</td>
</tr>
<tr>
<td>7. Percent of Number</td>
<td>The percentage of fixations during a maneuver allotted to each area</td>
<td>TN = N/ Σ N X 100</td>
</tr>
<tr>
<td>8. Scan Rate</td>
<td>The rate that each area was fixated</td>
<td>SR = N/ Σ T X 60</td>
</tr>
</tbody>
</table>
These visual data for each subject were combined into appropriate groups and the results are reflected by Tables 6 through 17 located in Appendix B. Tables 6 and 7 denote the percentages of lapse time along with the standard deviation for each group for each of the flight segments during which the thirteen areas were fixated. The data shown in Tables 8 and 9 are the percentages of fixations per instrument for each of the flight segments. The data depicted in Tables 10 and 11 represent the mean dwell time spent viewing each instrument. The presentation of the data in percentages and rates allows the results to be compared across maneuvers and subject groups regardless of subject variance in time required to complete the maneuvers.

The link values between the thirteen areas for each group of subjects are presented in Tables 12 through 17. The top values are link values of the low time aviators (SQA) while the lower values are for the instructor pilots (IQA).

Figures 6 through 13 (Appendix C) graphically illustrate the percentage of lapsed time each group spent within each area. The solid bar represents values for the IQA group and the broken bar those of the SQA group. Scan rate and lapsed time differences were minimal across groups; therefore, scan rate data are not presented.

From inspection of the mean values, it was determined that the RPM, electrical, oil, and fuel gauges comprised less than one percent of the scan rate or percentage of lapse time measures obtained during most of the maneuvers. Because these values were extremely low, and at times zero, they were eliminated from the statistical analyses. Additionally, the visual area labeled "all other areas" typically comprised only one percent of the total lapsed time and was deleted. Finally, the gauges described in the "torque" area were noted; but because this area represented three gauges which confounded the results and because it was not homogeneous with the remaining flight gauges, it too was excluded from the remaining tests. The statistical analysis was performed utilizing the remaining seven areas. These areas were the altimeter, vertical speed indicator, radio magnetic compass, attitude indicator, airspeed indicator, turn and bank indicator, and omni indicator. These instruments could best be described as aircraft flight displays, and those gauges which were excluded, as aircraft monitoring gauges. The final analyses were performed between two groups of subjects across the eight flight maneuvers. The visual performance measures of the seven flight instruments were utilized as dependent variables for these analyses.

Multivariate and univariate analyses were performed employing group scan rates, dwell times, and percentage of lapse times, to determine if one of these measures was superior in describing visual performance differences between subject groups or maneuvers. Initially, a multivariate analysis of variance test (MANOVA) of the percentage time
was performed between the two groups of subjects, eight maneuvers, and seven flight gauges. The results are shown in Table 18.

**TABLE 18**

MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY: PERCENT OF LAPSE TIME FOR ALL MANEUVERS

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>LESST THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>8.427</td>
<td>7.0</td>
<td>2.0</td>
<td>.110</td>
<td>.983</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>7.386</td>
<td>49</td>
<td>258.26</td>
<td>.001</td>
<td>.967</td>
</tr>
<tr>
<td></td>
<td>2.951</td>
<td>36</td>
<td>240.973</td>
<td>.001</td>
<td>.771</td>
</tr>
<tr>
<td></td>
<td>1.849</td>
<td>25</td>
<td>217.761</td>
<td>.011</td>
<td>.613</td>
</tr>
<tr>
<td>GROUP-MANEUVER</td>
<td>1.255</td>
<td>49</td>
<td>258.26</td>
<td>.135</td>
<td>.614</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.

The group and group-maneuver interactions were not significant; however, as was expected, there were differences across maneuvers. Next, from viewing the graphs in Figures 7, 8, and 9, the climb, cruise, and descent portion of the flight profile appeared to contain similar visual fixations data. Visual performance during these three maneuvers was tested by MANOVA and no significant differences were found between groups, the group-maneuver interaction, or across maneuvers (Table 19).
TABLE 19
MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:
PERCENT OF LAPSE TIME FOR CLIMB, CRUISE, DESCENT

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>2.683</td>
<td>7.0</td>
<td>2.0</td>
<td>.224</td>
<td>.918</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>.639</td>
<td>14.0</td>
<td>20.0</td>
<td>.804</td>
<td>.700</td>
</tr>
<tr>
<td>GROUP-MANEUVER</td>
<td>1.882</td>
<td>14.0</td>
<td>20.0</td>
<td>.096</td>
<td>.848</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.

Because these three maneuvers demonstrated no significant differences they were tested, in turn, against the remaining maneuvers. The results of these three maneuvers compared to the ITO are shown in Table 20, the ILS in Table 21, climbing turns in Table 22, descending turns in Table 23, and level turns in Table 24.

The MANOVA was utilized next to test the difference between group dwell times during each maneuver. Again, comparisons between visual dwell time during climb, cruise, and descent demonstrated no significant differences. These three maneuvers were compared in turn with each of the remaining maneuvers. Significant differences were found when data from these maneuvers were compared against the ILS (Table 25). When the scan rate data were submitted to an identical test, significant differences were observed between the three maneuvers, the ITO (Table 26) and the ILS (Table 27).
### TABLE 20
**Multivariate Analysis of Variance Summary:**
*Percent of Lapse Time for Climb, Cruise, Descent, ILS*

<table>
<thead>
<tr>
<th>Source</th>
<th>F-Ratio</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>P less than</th>
<th>Canonical R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>8.568</td>
<td>7.0</td>
<td>2.0</td>
<td>.108</td>
<td>.984</td>
</tr>
<tr>
<td>Maneuvers</td>
<td>2.624</td>
<td>21.0</td>
<td>52.236</td>
<td>.002</td>
<td>.903</td>
</tr>
<tr>
<td>Group-Maneuver</td>
<td>.941</td>
<td>21.0</td>
<td>52.236</td>
<td>.545</td>
<td>.723</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.

### TABLE 21
**Multivariate Analysis of Variance Summary:**
*Percent of Lapse Time for Climb, Cruise, Descent, ILS*

<table>
<thead>
<tr>
<th>Source</th>
<th>F-Ratio</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>P less than</th>
<th>Canonical R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>17.221</td>
<td>7.0</td>
<td>2.0</td>
<td>.056</td>
<td>.992</td>
</tr>
<tr>
<td>Maneuvers</td>
<td>6.445</td>
<td>21.0</td>
<td>52.236</td>
<td>.001</td>
<td>.979</td>
</tr>
<tr>
<td>Group-Maneuver</td>
<td>1.972</td>
<td>2.10</td>
<td>52.236</td>
<td>.024</td>
<td>.759</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.
### TABLE 22

**MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:**
**PERCENT OF LAPSE TIME FOR CLIMB, CRUISE, DESCENT, CLIMBING TURN**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>524.491</td>
<td>7.0</td>
<td>2.0</td>
<td>0.034</td>
<td>1.0</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>1.826</td>
<td>21.0</td>
<td>52.236</td>
<td>0.040</td>
<td>0.830</td>
</tr>
<tr>
<td>GROUP-MANEUVER INTERACTION</td>
<td>1.273</td>
<td>21.0</td>
<td>52.236</td>
<td>0.237</td>
<td>0.718</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.

### TABLE 23

**MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:**
**PERCENT OF LAPSE TIME FOR CLIMB, CRUISE, DESCENT, DESCENDING TURN**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>8.059</td>
<td>7.0</td>
<td>2.0</td>
<td>0.115</td>
<td>0.983</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>1.928</td>
<td>21.0</td>
<td>52.236</td>
<td>0.028</td>
<td>0.850</td>
</tr>
<tr>
<td>GROUP-MANEUVER INTERACTION</td>
<td>1.661</td>
<td>21.0</td>
<td>52.236</td>
<td>0.070</td>
<td>0.755</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.
### TABLE 24

**MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:**
**PERCENT OF LAPSE TIME FOR CLIMB, CRUISE, DESCENT, LEVEL TURN**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>5.495</td>
<td>7.0</td>
<td>2.0</td>
<td>.163</td>
<td>.975</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>2.346</td>
<td>21.0</td>
<td>52.236</td>
<td>.007</td>
<td>.860</td>
</tr>
<tr>
<td>GROUP-MANEUVER INTERACTION</td>
<td>1.282</td>
<td>21.0</td>
<td>52.236</td>
<td>.230</td>
<td>.773</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.

### TABLE 25

**MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:**
**DWELL TIME FOR CLIMB, CRUISE, DESCENT, ILS**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>.322</td>
<td>7.0</td>
<td>2.0</td>
<td>.892</td>
<td>.728</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>2.263</td>
<td>21.0</td>
<td>52.236</td>
<td>.009</td>
<td>.894</td>
</tr>
<tr>
<td>GROUP-MANEUVER INTERACTION</td>
<td>.963</td>
<td>21.0</td>
<td>52.236</td>
<td>.520</td>
<td>.740</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.
### TABLE 26
MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:
SCAN RATE FOR CLIMB, CRUISE, DESCENT, ITO

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>3.813</td>
<td>7.0</td>
<td>2.0</td>
<td>.223</td>
<td>.965</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>2.864</td>
<td>21.0</td>
<td>52.236</td>
<td>.001</td>
<td>.913</td>
</tr>
<tr>
<td>GROUP-MANEUVER INTERACTION</td>
<td>.714</td>
<td>21.0</td>
<td>52.236</td>
<td>.800</td>
<td>.671</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.

### TABLE 27
MULTIVARIATE ANALYSIS OF VARIANCE SUMMARY:
SCAN RATE FOR CLIMB, CRUISE, DESCENT, ILS

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>F-RATIO</th>
<th>HYPOTHESIS df</th>
<th>ERROR df</th>
<th>P LESS THAN</th>
<th>CANONICAL R</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUPS</td>
<td>4.287</td>
<td>7.0</td>
<td>2.0</td>
<td>.202</td>
<td>.968</td>
</tr>
<tr>
<td>MANEUVERS</td>
<td>7.115</td>
<td>21.0</td>
<td>52.236</td>
<td>.001</td>
<td>.980</td>
</tr>
<tr>
<td>GROUP-MANEUVER INTERACTION</td>
<td>1.168</td>
<td>21.0</td>
<td>52.236</td>
<td>.316</td>
<td>.716</td>
</tr>
</tbody>
</table>

Significant test uses Wilks-Lambda criterion. The third factor was subjects and was used in creating appropriate error terms for the primary comparisons.
It may be noted in the above multivariate comparisons that the
degrees of freedom for the test were relatively few in number, resulting
in an extremely conservative test of the experience level and maneuver
main effects. However, since the main purpose of these comparisons was
to determine if there were any major differences between visual per-
formance on these factors, this conservatism is considered appropriate.

Because of the results of the MANOVA, univariate F tests associated
with significant visual performance variables were examined as an aid in
describing changes in visual performance across maneuvers. The groups
differed in performance during climb, cruise, and descent only in the
percent of time fixated on the turn and bank indicator ($F = 11.087$, $DF = 1/8$, $P < .01$). This same group difference was found testing each of the
remaining maneuvers as illustrated in the test of the three maneuvers
against the ITO ($F = 21.222$, $DF = 1/8$, $P < .002$). There were no other
group differences noted during the univariate tests of the percentage of
time, scan rate, or the dwell times.

The significant results of the univariate F test of the maneuvers
utilizing percentage of lapsed-time measure are presented in Table 28
and the results of the same test of the maneuvers with the scan rate
measure are shown in Table 29.
### Table 28
**Univariate F Test of Maneuvers/Percent of Time**

<table>
<thead>
<tr>
<th>Maneuvers/Scan Rate</th>
<th>ALT</th>
<th>VSI</th>
<th>TAB</th>
<th>RM</th>
<th>AH</th>
<th>AS</th>
<th>OBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climb, Cruise, Descent</td>
<td>F</td>
<td>9.61</td>
<td>13.44</td>
<td>8.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and ILS</td>
<td>F</td>
<td>14.05</td>
<td>3.84</td>
<td>5.41</td>
<td>7.83</td>
<td>7.66</td>
<td>146.75</td>
</tr>
<tr>
<td>Climb, Cruise, Descent and Descending Turns</td>
<td>F</td>
<td>4.02</td>
<td>11.71</td>
<td>3.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and Climbing Turns</td>
<td>F</td>
<td>3.60</td>
<td>7.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and Level Turns</td>
<td>F</td>
<td>3.43</td>
<td>6.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 29
**Univariate F Test of Maneuvers/Scan Rate**

<table>
<thead>
<tr>
<th>Maneuvers/Scan Rate</th>
<th>ALT</th>
<th>VSI</th>
<th>TAB</th>
<th>RM</th>
<th>AH</th>
<th>AS</th>
<th>OBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climb, Cruise, Descent</td>
<td>F</td>
<td>4.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and ILS</td>
<td>F</td>
<td>6.45</td>
<td>8.75</td>
<td>5.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and Descending Turns</td>
<td>F</td>
<td>11.94</td>
<td>3.14</td>
<td>9.26</td>
<td>16.67</td>
<td>126.73</td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and Climbing Turns</td>
<td>F</td>
<td>4.71</td>
<td>6.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb, Cruise, Descent and Level Turns</td>
<td>F</td>
<td>4.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22
A stepwise discriminant analysis was performed utilizing the scores of the seven instrument flight displays which had previously been chosen. Separate analyses were performed for the percent of lapse time, scan rate, and dwell time. A stepwise discriminate analysis was utilized to determine if the variables could effectively define changes in visual performance between groups and maneuvers. The two subject groups were tested to determine if they could be classified by the 39 variables. Table 30 reflects the results of this test. From these results, it can be demonstrated that dwell time was not a good discriminator of groups.

**TABLE 30**

**STEPWISE DISCRIMINANT ANALYSIS CLASSIFICATION OF SUBJECT GROUPS**

<table>
<thead>
<tr>
<th>VARIABLE USED</th>
<th>GROUP</th>
<th>CLASSIFIED AS:</th>
<th>SQA</th>
<th>IQA</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwell Time</td>
<td>IQA</td>
<td>11 27 71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SQA</td>
<td>26 12 68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scan Rate</td>
<td>IQA</td>
<td>7 31 84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SQA</td>
<td>32 6 81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of Time</td>
<td>IQA</td>
<td>7 31 84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SQA</td>
<td>33 5 86</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Finally, the same stepwise discriminant analysis, utilizing the seven variables simultaneously, was performed to determine if the maneuvers could be correctly classified. Tables 31 through 34 reflect the results of these tests.

**Psychomotor and Aircraft Performance:** Psychomotor and aircraft performance was measured via the HIMS. Because of equipment malfunctions, some of these data were lost. Of the ten subjects, two SQA psychomotor/aircraft data were lost and three from the IQA group. Table 35 is the two group psychomotor parameters and Table 36 the aircraft parameters. The SQA group demonstrated a trend of less control inputs and more time in control steady state (Table 35). They also had a better aircraft performance (Table 36).
### Table 31

**Stepwise Discriminant Analysis**

Classification of maneuvers utilizing percentage of lapse time

<table>
<thead>
<tr>
<th></th>
<th>Climb</th>
<th>Cruise</th>
<th>Descent</th>
<th>Climbing Turn</th>
<th>Descending Turn</th>
<th>Level Turn</th>
<th>ILS</th>
<th>ITO</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climb</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Cruise</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>Descent</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>64</td>
</tr>
<tr>
<td>Climbing Turn</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>12</td>
</tr>
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**Stepwise Discriminant Analysis**

Classification of Maneuvers Utilizing Percentage, Dwell Time, Scan Rate

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Questionnaire: Following each test flight, subjects were provided a pilot's opinion questionnaire which had been prepared for USAARL Report No. 76-18, "Pilot Opinion of Flight Displays and Monitoring Gauges in the UH-1 Helicopter." An example of this questionnaire is in Appendix A. The sections of the questionnaire which closely relate to the objective data are the frequency of use and importance which each aviator rated the flight instruments during climb, cruise, and descent. Current aviator responses were compared to responses of the original group of aviators who had answered these same questions. For each section and display category, a Kendall's Coefficient of Concordance (W) was computed to determine the relationship between ranks for the two subject groups. The coefficient of concordance (W) for the two groups for the frequency of use of the flight display during climb, cruise, and descent as well as the order of importance were significant at the .01 level indicating a high level of agreement between the two groups. Current and past aviator opinions are presented in Table 37. Figure 14 reflects the mean responses of how often or how rarely the aviators felt they used the flight instruments.
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DISCUSSION

The visual data which have been reported to this point were collected to develop a pilot visual performance data base during helicopter flight. The maneuvers were flown under instrument flight rules, and varied from an ITO through climbs, cruise, descents, and turns, which are basic IFR maneuvers with no navigation tasks, and finally included an ILS. Aviator visual performance during these maneuvers is quite complicated as is indicated by the numerous tables and figures which have been utilized thus far in an attempt to describe the data.

The data base is essential however, because there appears to be no other method to determine what cues are required for safe helicopter flight. The questionnaire data demonstrate, when compared to Figures 5 through 16, that aviators' opinions do not agree with their own objective visual data. Although subjectively aviators feel that the attitude indicator and radio magnetic compass ranked very low in priority of use, visually they depended very heavily on the same two instruments. The visual performance related to these two instruments combined accounted for two-thirds of their total visual lapse time across all maneuvers.

Utilization of the attitude indicator and radio magnetic compass seems to indicate that pilots place a high priority on maintenance of the aircraft's stability about its major axes (pitch, roll, and yaw). The data of the present study would support this assumption in that before a pilot can utilize fine detailed information about his flight, he needs to determine that the aircraft is positioned spatially about these three axes. Only after this is ascertained would the pilot scan other instruments for fine detail.

Projecting this line of thought, the instrument panel can be divided into three separate zones. The first zone which could be labeled "aircraft stability management" would include the attitude indicator for pitch and roll information, and both the radio magnetic compass and turn and bank indicator for yaw information. Data obtained about the turn and bank link values (Tables 12 through 17) support that it be classified with the other two instruments. To gain this stability information from these instruments would require the pilot to perform simple visual tracking tasks in contrast to reading quantitative information from other instruments such as the altimeter or airspeed indicator.

The second zone provides the finely detailed information about current aircraft status such as exact altitude or airspeed. This zone could be labeled "quality flight management" and would include the altimeter, airspeed indicator, and vertical speed indicator. Instruments in this zone would be utilized only when the monitoring of zone one was not critical.
The final zone would be comprised of the remaining instruments which include special navigation instruments and aircraft monitoring gauges. This third zone could be termed "special requirement gauges." These gauges are not vital for normal flight but are monitored or used only on as-time-allows or on a need-to-know basis. These zones are illustrated in Table 38.

### TABLE 38

<table>
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<tr>
<th>ZONE I</th>
<th>1. ATTITUDE INDICATOR</th>
<th>2. RADIO MAGNETIC COMPASS</th>
<th>3. TURN AND SLIP INDICATOR</th>
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<td>ZONE II</td>
<td>1. ALTIMETER</td>
<td>2. AIRSPEED INDICATOR</td>
<td>3. VERTICAL VELOCITY INDICATOR</td>
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<td>ZONE III</td>
<td>1. AIRCRAFT MONITORING GAUGES</td>
<td>TORQ, RPM, ELEC OIL, FUEL OBS REST</td>
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<td></td>
<td>2. SPECIAL NAVIGATION INSTRUMENTATION</td>
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<td>3. ALL OTHER VISUAL AREAS</td>
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If these zones adequately describe aviator visual performance during IFR flight in a helicopter, the twenty-three instruments utilized by the pilot have been reduced to three zones. The visual performance data from this investigation describe the percentage of lapse time, scan rate, and dwell time along with link values of these zones. However, the importance or cost of a zone or gauge can be described by the sum of the frequency that an area is visually fixated and the average time fixated in that area (dwell time). The lapse time and number of fixations on the gauges can be utilized to derive this single value. The formula would appear as: \[ CF_z = \frac{T \sum T + N \sum N}{2} \]. CF represents the "cost factor" of each zone, "T" is in seconds, and "N" is number. If this value is divided by two, the CF is in percentage of workload.

If the above formula is utilized, the data in this study can be reduced to a single value for each of the three zones across eight flight maneuvers. The CF value reflects the percentage of time, scan
rate, and dwell time as one value. The only variable not accounted for is link value. This value simply represents "how well" the panel was arranged. This assumption is supported by Senders, et al. 

A summary graph for the three zone/cost factor approach is represented by Figure 15. The solid line represents the SQA aviators and the broken line the IQA.

Each zone represented on the graph has a distinct level of visual work cost. Zone 1 utilizes approximately 60% of the total effort; Zone 2, 30%; and Zone 3 less than 10%. Zone 2 effort is increased only as Zone 1 decreases and Zone 3 remains fairly constant with the exception of the ILS maneuver. The reason for this observation could be that the ILS was different from all the other maneuvers in that it included not only basic flight but also a navigation problem. Zones 1 and 2 have
distinct workload points for the ITO and ILS maneuvers with the rest of the maneuvers requiring some effort allotted between these two maneuvers. The ITO appears to be the least stable maneuver requiring maximum work cost within Zone 1 while during the ILS the utilization of Zone 1 is at its lowest point. Since both maneuvers are considered to be high workload situations, these values in Zone 1 could represent a maximum and minimum workload required in the zone to afford stability management of a helicopter. Notice that during these same two maneuvers Zones 2 and 3 are at the same workload levels from one maneuver to the other. This demonstrates that as workload increases, both of these areas are sacrificed.

The fact that all maneuvers other than the ITO and ILS are at a level of less than maximum effort, and more than minimum effort in Zone 1, could represent some rest time that is not essential to flight.

The statistical analysis which was previously completed supports the Zone/CF theory to a large degree. The values which comprise the CF were tested separately. The MANOVA and univariate F of the percent of lapse time, scan rate, and dwell time (CF value) found no differences between the climb, cruise, and descent maneuvers and found minimal differences when these were compared with the turn maneuvers. The major differences were found when comparing CF values of the ITO and ILS maneuvers to the "flight" maneuvers; likewise, the stepwise discriminant analysis utilizing the same three criteria could classify only the ILS and ITO with any accuracy.

The univariate F test found differences in the percent of lapse time and scan rate of altimeter, vertical speed indicator, radio magnetic compass, and the attitude indicator when comparing the climb, cruise, and descent maneuvers with the ITO. Reviewing the mean values demonstrates that the usage of the gauges in Zone 2 (ALT and VSI) was depressed while Zone 1 (AH and RMI) required more attention during the ITO. The OBS gauge was significant only during the comparison of the three flight maneuvers with the ILS. Finally, the turn's CF values were significantly different from climb, cruise, and descent because of the rearrangement of usage of the instruments within Zone 2. These conclusions are also supported by the graph in Figure 15.

The univariate F test revealed the only significant difference between subject groups was their use of the turn and slip indicator. The stepwise discriminant analysis also was able to discriminate groups mainly by their usage of this same instrument. Therefore, Zone 1 for the two groups was expanded and the results appear in Figure 16.
The visual performance on the radio magnetic compass has varying results across groups. However, the attitude indicator (with the exception of descending turns) and the turn and bank indicator do show distinct level differences between groups. These data compared to the HIMS data in Tables 35 and 36 demonstrate that the IQA group utilized the T&B the most and had the least pedal control stability. Other investigators have explained this as a single channel response describing that a subject will monitor that area which changes the most.18 Finally, it should be noted that with the exception of the difference of the two groups within Zone 1, their CF performance paralleled one another (Figure 15). The total visual workload of the SQA was lower in Zone 1 than the IQA, allowing the SQA more time for Zone 2 and better aircraft control. This usage of Zone 1, as other data are indicating, could reflect a major difference of proficiency levels with the SQA being the more currently proficient.
This study was initiated to investigate the visual performance of pilots flying during helicopter IFR maneuvers. The study of IFR maneuvers was unique because the aviators were forced by conditions to receive any and all of their visual cues to manipulate the aircraft from an instrument panel. This limited visual field allowed investigators to analyze which cues were fixated and derive what information was visually obtained by the pilot. During VFR this extraction of visual performance would be very difficult because of lack of precise definitions as to the quality of possible VFR cues.

The data reflected in Tables 6 through 17 and Figures 6 through 13 represent pilot visual performance during the various maneuvers of this project. This information is useful in itself in describing general visual performance during helicopter flight. Some conclusions can be noted from this data.

a. When compared to Fitts, Jones, and Milton's visual studies in fixed wing aircraft during IFR maneuvers, it is readily apparent that the percentage of utilization of the RMI and AH are reversed during helicopter flight with the AH being utilized the most.

b. During helicopter flights the AH and RMI comprised over 50% of the total visual performance with no other instrument being utilized one-half the time of either instrument with one exception—the ILS maneuver.

c. The mean dwell time for instruments with simple pointer systems such as the AS, ALT, and VSI was 400 to 500 milliseconds while more complex instruments such as the RMI and AH required 500 to 600 milliseconds.

d. Oil, fuel and electrical gauges were each observed less than one percent of the time. If consideration is given to this fact, it can be interpreted in the sense that each aviator has less than a one percent chance of detecting any malfunction reflected by these gauges.

e. The link values reflect that the major scan pattern utilized by the helicopter pilots was to use the AH and RMI as base of visual information from which they darted out to other areas briefly and back to the base again.

f. Subject opinion data did not agree with the objective visual data.
The above results have a basic application in describing visual performance during helicopter operations. However, because of the numerous tables and figures involved it becomes extremely difficult to attempt to predict or model visual performance/workload in other aircraft or during other operational missions. To attempt to combine all the useful information into a more concise package, the visual zone/cost factor was introduced. The zones were ranked as to their visual importance to the pilot with the aircraft stability management zone being the most important. The cost factor accounted for the frequency and duration of the pilot's fixation to describe his total visual requirements. This formula provides some possible useful alternatives.

a. The usage of Zone 1 between groups of subjects could describe current proficiency differences as described in the discussion section.

b. It could also be predicted that a significant reduction in Zone 1 could be accomplished by providing a more stable helicopter platform as in fixed wing aircraft. Such a reduction would provide more visual time for other tasks such as monitoring of other gauges or attending to other mission needs. Additionally, because Zone 1 comprises over 55% of the visual workload, any visual performance reduction in this area would have significant savings in visual workload.

c. With the minimum and maximum visual workloads in Zone 1 noted for the ITO and ILS maneuvers, perhaps accidents during inadvertent instrument flight could be explained as exceeding the minimum visual workload in this zone for aircraft stability management.

This study should not conclude visual performance/workload but should assist in developing a data base for predicting visual performance/workload during flights in aircraft of varying stability and during adverse weather missions dictated by military requirements. The application of this and similar information to aircraft panel design could ultimately provide the significant factor which determines safe tactical mission accomplishment.
REFERENCES


7. Sanders, M. G. Personal communication based on data being prepared for publication. November 1976.


APPENDIX A

Visual Performance Impressions Questionnaire
II. FREQUENCY OF USE (Cont'd)

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| 2.     | I frequently refer to this instrument. |                     |   |                          |     |             |                   |
| 3.     | I occasionally refer to this instrument. |                     |   |                          |     |             |                   |
| 4.     | I rarely refer to this instrument.     |                     |   |                          |     |             |                   |
| 5.     | I never refer to this instrument.     |                     |   |                          |     |             |                   |
## II. FREQUENCY OF USE

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**II. FREQUENCY OF USE**

- 1. I would never trust this instrument.
- 2. This instrument is frequently unreliable.
- 3. This instrument is as reliable as any.
- 4. I normally find this instrument to be reliable.
- 5. I consider this instrument highly reliable.
APPENDIX B

TABLES 6 through 17
TABLE 6
PERCENT OF VISUAL LAPSE TIME (%T)

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APPENDIX C

FIGURES 6 through 13
FREQUENCY OF FIXATIONS DURING ITO

PERCENT OF TIME

FIGURE 6
FREQUENCY OF FIXATIONS DURING CLimb

FIGURE 7
FREQUENCY OF FIXATIONS DURING CRUISE

FIGURE 8
FREQUENCY OF FIXATIONS DURING DESCENT

FIGURE 9
FREQUENCY OF FIXATIONS DURING CLIMBING TURN

FIGURE 10
Flight under instrument flight rules (IFR) is reported to be one of the most important factors contributing to aviator fatigue during helicopter operations. This study was initiated to collect visual and psychomotor performance data in an attempt to investigate and study the general visual performance of aviators during IFR conditions. Two groups of aviators, with varied experience levels, were the subjects.

A MAC Eye Mark Recorder and the Helicopter In-Flight Monitoring System were utilized to collect the required data. The results indicated, among other findings, that pilot subjective opinion does not agree with objective data. Additionally, the attitude indicator and radio compass comprised over 60% of the pilots' total visual workload, while the aircraft's status gauges were monitored less than 10% of the total time. These data should provide invaluable information concerning the visual requirements of pilots for safe helicopter operations.

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Addendum

Footnotes 1 and 2 were inadvertently left off Table 35 located on page 28 of this report. They are as follows:

1Movements per second.  
2Percent of steady state.