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EVALUATION OF THE EFFECTS OF PILOTAGE SENSOR FIELD OF VIEW AND LOCATION ON THE PERFORMANCE OF DISPARATE FLYING TASKS

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Abstract

The purpose of this study was to investigate the effect of pilotage sensor field-of-view (FOV) size and location on pilot performance. Eight pilots performed disparate flying tasks (nine precision ADS-33 maneuvers and a contour course) in the Crew Station Research and Development Facility (CSRDF) advanced rotorcraft simulator. Sensor FOV size and location was examined in a four (FOV) by two (sensor location) by two (replications) within-subjects factorial design. The four main FOV sizes were 20°, 35°, 60°, and 100° horizontal with vertical FOV size held constant at 40°. Sensor location was either at the pilot's cyclopean eye point or on the nose of the aircraft (2.28 m forward and 1.10 m down from pilot's eye). A control condition (unrestricted 120° x 60° FOV with sensor location at pilot's eyepoint) and two special cases (52° x 35° and 80° x 40° FOV with sensor location on aircraft nose) were also examined. Summarizing the objective data, three variables showed reliable effects of varying FOV on performance of two flight tasks. Performance benefits derived from increasing FOV from 50° to 80° varied from just under 10% to over 25%. Pilot workload ratings also showed a significant effect of FOV size on flight performance for all the maneuvers. Workload ratings were reliably higher in the 20° x 40° FOV condition and lower in the 100° x 40° condition.

Helmet-Mounted Display FOV Size

With unmediated vision, helicopter pilots enjoy an instantaneous FOV of approximately 180° horizontal by 120° vertical (Ref 1 and Ref 5). When vision is mediated by an electronic sensor-display combination, the instantaneous FOV display is typically 60° or less. The electronic helmet mounted displays (HMDs) presently used for pilotage have FOVs of 40° or less. These systems are intended for use at night. In the near future, display FOVs will not be much larger in size. There are plans to employ HMDs for both day and night flight, with a FOV of over 50°. Farther in the future, sensors and displays may achieve 80° x 40° FOV.

To compensate for the restricted, instantaneous FOV, helicopter pilots may continually scan the out-the-cockpit scene to detect and avoid obstacles, and to navigate. Scanning may not fully compensate for the effects of the narrow FOV of these devices. The existing pilotage systems displays have frequently been criticized for having too narrow a FOV. Interestingly, an analysis of accidents where night vision goggles (NVGs) were used, failed to find evidence that the pilotage image intensifier device was a major contributor to the accidents (Ref 3).

Everyone, including pilots, engineers, and visual scientists, who has considered the question of FOV size agrees that a larger FOV is better than a smaller one, and that the natural limit of 180° horizontal by 120° vertical is the best alternative. However, there is little agreement about what is the minimum acceptable FOV size that should be afforded to aviators. Opinions of what is adequate or required range from 60° horizontal by 30° vertical to 120° horizontal by 60° vertical.

For sensor and intensified image displays, there are trade-offs between FOV size and one or more of the factors of resolution, weight, and cost (Ref 6). For example, FOV and resolution are commonly traded-off in sensor display design because a fixed number of sensor or display pixels can be concentrated in a small FOV area or spread-out over a large FOV area. In some cases, the sensor technology is essentially a limiting factor. Never-the-less, to begin to make trade-off decisions, knowing how FOV size affects flight and mission performance is important.

In the context of U.S. Army aviation, a number of analytic and empirical studies have been performed to determine FOV effects on performance and workload of helicopter pilots. In aviation, more generally, many studies have addressed FOV requirements for displays and cockpit window sizes. In addition, a large body of the simulation research literature is devoted to the question of simulator FOV requirements for training (Ref 4).

In almost all empirical studies, the dependent measures have been some set of meaningful flight performance measures, such as attitude maintenance, path navigation, landing speed and position, target detection and obstacle avoidance. However, none of these studies has produced unequivocal results showing marked changes in performance with FOV size. One supportable conclusion from the literature is that differences in performance are not readily manifest as a function of FOV size over the current range of interest, i.e., 40° to 120° (horizontal) and 30° to 80° (vertical). The apparent reason for this state of affairs is not because FOV size can affect performance but rather because the performance measures have been too insensitive to discover a statistically reliable difference. In balance, it should be pointed out that subjective measures support the need for FOVs larger than 40°, and task performance trends generally are consistent with subject's opinions.

One reason for the difficulty of showing effects of FOV on flight performance is the generality of the question. Prior research has rarely considered what visual functions are affected by FOV. Also, the dependent performance measures are usually chosen because of their importance to mission success and not because of a predicted sensitivity to FOV size. For example, typical performance measures are flight path and altitude accuracy, target detection, and number of collisions. Moreover, scenarios are not tailored to provoke specific behaviors that mediate between perception and flight control. Simply put, there is a lack of constructs to link visual functions sensitive to FOV size to behaviors that are targeted by appropriate measures.

Since future electronic sensor-displays will have proposed FOV sizes ranging between 50° to 80°, we were interested in investigating the issues concerning the effects these particular FOV sizes may have on helicopter pilotage.

Sensor Location

The image intensifier tubes are located in front of the eyes and do not appreciably alter the pilots natural viewpoint. Electronic sensors, on the other hand, must be located remotely from the pilot. Usually the sensor location of choice is on the nose of the aircraft. Consequently, the pilot's viewpoint moves to the sensor location when it is employed. The remote viewing point has advantages. The adaptation literature would predict that the pilots would soon adapt to the altered viewpoint and would eventually perform as well as if they were seeing from the conventional viewpoint in the cockpit. However, there are other, more subtle differences that accompany the displacement of the pilot's viewpoint. For example, the view of the familiar structure of the cockpit and windscreen struts interposed in the pilot's FOV helps the pilot to literally know where his or her head is at (Ref 2). The pilot can determine the direction of gaze by reference to symbology appearing on the display. A head marker can show the direction of gaze, albeit requiring attention from the pilot. A sensor view is usually unobstructed, and therefore lacks visual cues to the direction of gaze. However, the absence of the structures also means that the objects in the scene will not be masked. Sensors, like the head, have some limit of movement in azimuth and elevation, but eventually hit a stop.

Head turn limits are greater than those of sensors. Consequently, when a head movement is made that is larger than the gimbal limits of the sensor, a disorienting stimulus will result when the sensor stops moving while the head keeps going. Disorientation can also occur if the sensor is not roll compensated. Lastly, with a nose-mounted viewpoint the pilot is at a disadvantage for judging the side clearance of the rotor blades and the clearance of the tail boom. In short, sensor displacement of viewpoint is not a trivial or transitory issue and is worthy of investigation. Since FOV restrictions and sensor location are shared characteristics of existing and future electronic sensors and displays, it makes sense to investigate both variables in applied research studies of mediated vision with HMDs.

Method

Subjects

Eight right-handed, male pilots participated in this study (one pilot was unable to complete the study due to simulator sickness). The pilots ranged between 32-47 years in age, had 20/20 vision (or vision corrected to 20/20), and an average of 4,066 total flight hours. In addition, the pilots had an average of 229 simulator hours of previous rotorwing simulator experience. These pilots were recruited from local U.S. Army reserve, U.S. Navy, or National Guard units, the Night Vision Electronic Sensors Directorate (NVESD) in Ft. Belvoir, Virginia, and DRA Farnsborough, Great Britain. All the pilots that participated in this study were recruited as volunteers.

Apparatus

The experiment was conducted utilizing the Crew Station Research and Development Facility (CSRDF) full-mission, advanced rotorcraft simulator. The CSRDF consists of a cab with two tandem seats on a fixed base platform. For the purposes of this experiment, the simulator was operated from the front cockpit by a single pilot. The front cockpit Tactical Situation Display (TSD) was used to display airspeed and barometric altitude information to the pilot.

The CSRDF visual display is the CAE Fiber-Optic Helmet Mounted Display (FOHMD). This display, produced by a General Electric Compu-Scene IV computer-generated image (CGI) system, has two background eye (right and left) channels that provide 80° horizontal by 60° vertical images with 6 arc minutes resolution. With 40° of binocular overlap, the background channels together provide an instantaneous binocular Field-Of-View (FOV) of 120° x 60°. Two additional display channels are optically inset in the center of the binocular overlap area. This high resolution inset covers an area of 25° x 19°, and provides approximately 2 arc minutes resolution. The visual scene is projected onto partially reflecting mirrors on the CSRDF helmet using fiber-optic cables (the total weight of the custom-fitted helmet is approximately 2.5 kg, or 5.5 lbs). The angular position of the helmet is sensed optically using infrared light-emitting diodes.

The standard CSRDF visual database, depicting a generic European terrain, was used in this study. The overall size of the database is 2525 square nautical miles and consists of various types of terrain, roads, towns, lakes, rivers, and peaks. In order to mimic NVG ambient light intensification characteristics, the visual database was displayed in monochrome green.

The primary means of controlling aircraft flight is through the use of two 4-axis limited displacement hand controllers and foot pedals (the functional characteristics of the Blackhawk UH-60 was used as a flight model). A 2-1-1 flight control configuration was used: a) The right-hand controller was used as the cyclic (two axes - pitch and roll), b) the left-hand controller was used as the collective (one axis - altitude), and c) the foot pedals controlled yaw (one axis).

The sensor display FOV was modified using focal-plane masks. These interchangeable focal-plane masks were comprised of black cardboard cut-outs that were mounted onto the pilot's helmet, between the Optical Combiner and the Pancake Window Assembly, directly in front of the pilot's eyes.

Stimuli

The flight tasks consisted of nine precision maneuvers and a contour course task. Seven of the nine precision maneuvers were based on a draft of the Aeronautical Design Standards (ADS) - 33 document (Ref 7). The precision maneuvers performed were: Hover, hover turn, pirouette, acceleration/deceleration, sidestep, slalom, bob-up & down, recovery to hover, and the ever-narrowing gulch (see Appendix A). The maneuver parameters were outlined in the visual database by white reference markers (cones and poles). The contour course task, approximately 25 km (15.6 miles) in length, was comprised of pairs of tanks used by the pilots as visual waypoints (each tank pair was lined up with both turrets/guns pointing in the direction of the next pair of tanks). A total of 17 pairs of tanks was used in each of the eight contour courses, each pair of tanks spaced 1.6 km (1 mile) apart.

Design

Sensor display FOV size and sensor location was examined in a four (FOV) by two (sensor location) by two (replications) within-subjects factorial design. In addition to the main experimental design, a control condition and two special case FOV's were also included. The order of presentation of the FOV size and sensor location variables was randomized using a balanced Latin Square design.

The four FOV sizes were varied between 20°, 35°, 60°, and 100° horizontal with vertical FOV size held constant at 40°. The horizontal FOV sizes were selected to represent equal logarithmic steps in size. Twenty degrees was chosen as the narrowest FOV to increase the probability that performance would change as a function of FOV.

Sensor location was divided into two levels: a) At the pilot's cyclopean eye point, and b) on the nose of the aircraft. The sensor position on the aircraft nose was offset from the pilot's eyes by 2.28 m (7.48 ft) forward and 1.10 m down (3.61 ft).

The control condition consisted of an unrestricted 120° x 60° FOV, viewed under a monochrome green environment. Sensor location was at the pilot's eye point. Each pilot ran in a control condition session at the beginning and at the end of the week of testing. Two special cases were also investigated: a) 52° x 35° with an 18° binocular overlap, and b) 80° x 40°. The sensor location for both special case sessions was on the nose of the aircraft. The two special cases were conducted once each on the final day of the week of testing.

Three types of performance measures were collected in this experiment: a) Flight and mission performance, b) head-movements, and c) subjective pilot ratings. Flight performance measures used continuous variables such as aircraft attitude, horizontal position, and altitude. Error measures were defined as mean deviations from pre-established criteria values (e.g., flight path, initial position, etc.). Measures of variability were based on Root Mean Square (RMS) calculations for the continuous variables. The RMS components were separated into constant error and variability with respect to the mean value. Flight performance event measures included collisions with the ground and/or other objects, number of waypoints missed, etc. Flight event measures were based primarily on specific maneuver requirements (i.e., in accordance with ADS-33). These measures include deviations about the mean bearing to the center of the circle (pirouette), deviation from the center line while passing between a series of obstacles (gulch), etc.

Two types of subjective ratings were collected from the pilots: a) Aggression & Precision Ratings, and b) workload and acceptability ratings. The pilot gave aggression & precision ratings after completion of the two repetitions of a specific maneuver. For these ratings, the pilot evaluated the ability to achieve effective stabilization and control of the aircraft during the conduct of the aggressive and precise maneuver. A five point rating scale was used by the pilot to assess control of aircraft attitude (pitch, yaw, and roll axes), horizontal translation rate, and vertical translational rate. At the end of each session, the pilot used a seven-point rating scale (Likert rating scale where 1 = low acceptability and 7 = high acceptability) to rate the workload required to perform each maneuver, the overall workload, and the acceptability of the FOV and sensor location for supporting specific missions or tasks.

Procedure

Eight pilots participated in this experiment over an eight-week period. Two pilots participated in one week of testing, separated by one week before the next pair of pilots arrived for testing. Each pilot performed one familiarization and two training sessions before the start of data collection. Upon completion of the practice sessions, each pilot performed 12 experimental sessions: a) Two control condition sessions, b) eight main experiment sessions, and c) two special case sessions. Each session was approximately one hour in length.

Before the simulation started, both pilots received both a study and a CSRDF flight control briefing. The study briefing introduced the pilots to the experiment (i.e., purpose, design, and performance measures), the maneuvers, and the experiment schedule. The flight control briefing gave the pilots an overview of the CSRDF's flight controls and control laws. In addition to these briefings, the pilots had custom-fit flight helmets manufactured and received a safety briefing before commencing with the first familiarization session in the CSRDF.

In the familiarization session, the pilot was given an opportunity to become familiar with the CSRDF flight controls and handling qualities, as well as the monochrome green visual display. In order to facilitate learning, unrestricted FOV, a Head-Up Display (HUD) with basic flight symbology, and all available flight control holds were given to the pilot for the first training session. The flight control holds allowed the pilot to maintain aircraft flight control with reduced pilot input. The additional training sessions gave the pilot the opportunity to practice the maneuvers with different FOV sizes (35° and 100° horizontal by 40° vertical) and sensor locations (pilot eye point and aircraft nose).

After completion of training, all sessions were performed with barometric and velocity flight control holds (minimum number of holds required to control aircraft satisfactorily), and with airspeed and barometric altitude information located on the cockpit TSD. In addition, each session began with the pilot performing four practice precision maneuvers (hover, pirouette, acceleration/deceleration, and bob-up & down) so that the pilot could become familiar with the FOV and sensor location for that specific session.

Each of the sessions began with the pilot performing four practice precision maneuvers corresponding to a single FOV and sensor location. Upon completion of the practice maneuvers, the pilot commenced to fly nine pairs of the precision maneuvers and one contour course, for a total of 19 trials. After each pair of maneuvers was completed, the pilot would be asked to give Aggression & Precision Ratings for that specific set of maneuvers. Once the session was finished, the pilot filled out a pilot rating sheet that assessed workload and FOV/sensor location acceptability.

The pilots were debriefed once the test week concluded. In the debrief, the pilots were queried about the FOV size and sensor location effects on flight performance, the experimental design, CSRDF simulator performance, recommendations for future studies, and asked if they had any other questions/comments they wanted to add.

Results

Objective Data

Aircraft position and attitude data were recorded on the simulator at a 30 Hz rate. The first step in analyzing the data was to review a sample of the runs for each task visually. This review was accomplished using software developed at CSRDF on a Silicon Graphics workstation that animated a helicopter model. With this equipment it was possible to view a replay of all, or a portion, of each run with the aircraft and ground references visible. We identified three flight tasks for which the quality of aircraft handling appeared to be affected by changes in FOV. These tasks were the slalom, the pirouette and the gulch.

We then generated plan view plots of the aircraft ground track for a sample of runs on each of these three tasks. We examined the ground tracks in order to identify specific variables that might reveal FOV or sensor position effects. These data were subjected to a 2 x 4 (sensor position by FOV) repeated measures analysis of variance (ANOVA)[1]. Where reliable FOV effects were found, we performed post hoc analyses to address our primary issue, the effect on flying performance of increasing FOV from 50° to 80°.

We addressed the 50° vs. 80° question by first looking for a linear trend in the data, using a Pearson product-moment correlation coefficient (r). If the relationship between FOV and performance were nonlinear, then there would be a FOV at which there is a discontinuity (zero- or first- order) beyond which increases in FOV would yield minimal benefit. On the other hand if the relationship were linear, the performance gains could be characterized by a simple function of benefit per degree of increase over the entire range.

Sensor Location Effects. Since the ANOVAs for all variables and tasks showed no effect of sensor position, we collapsed the data across sensor position and used all seven FOVs in subsequent analyses.

FOV Size Effects. The pirouette was the most straightforward task to analyze since both aircraft position and aircraft attitude were specified by the task. The correct aircraft position always fell on a circle 30.5 m (100 ft) from the central pylon. The correct attitude was always for the aircraft to be headed toward the central pylon.

Attitude did not vary reliably with changes in FOV. Two measures of aircraft position error did vary reliably with FOV. The root mean square (RMS) position error decreased significantly with increasing FOV ($F[3,18] = 3.29$, $p < 0.05$). The maximum deviation from the correct position also decreased with larger FOV ($F[3,18] = 8.19$, $p < 0.05$).

Both variables showed a strong linear relationship to FOV. The correlation between RMS position error and FOV was -0.94 ($p < 0.05$). We looked at the effect of increasing FOV from 50° to 80° by evaluating the regression function. The value of the regression function was 3.72 m (12.2 ft) at 50° and 2.83 m (9.3 ft) at 80°. The benefit obtained by increasing FOV from 50° to 80° was 0.88 m (2.9 ft) or 23.9% (see Fig. 1). We obtained a similar result for the maximum deviation from the pylon. The correlation coefficient was -0.83. Maximum error dropped from 8.5 m (27.9 ft) to 6.28 m (20.6 ft), an improvement of 2.2 m (7.3 ft) or 26.2% (see Fig. 2).

The gulch also had two defined performance requirements. The pilots were to follow the winding path, so deviation from the centerline provided one performance metric. Their second requirement was to keep the main rotor from striking the pylons as these got closer together over the course. This task was unorthodox, to say the least, and the pilots adopted some unorthodox techniques for attempting it. As a result, there was no reliable effect of FOV. There

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[1] The two special cases, 52° and 80°, and the 120° control condition were omitted from the ANOVA because they had empty cells. In all cases, however, the data obtained for these conditions was generally in accord with the data from the other FOV conditions.

was, however, a reliable effect of FOV on deviation from the centerline (F[3,18] = 9.05, $p < 0.05$). There was a significant linear trend ($r = -0.83$, $p < 0.05$). The effect of increasing FOV from 50° to 80° was to reduce deviation from the centerline from 4.3 m (14.1 ft) to 3.87 m (12.7 ft), a reduction of 0.43 m (1.4 ft) or 9.8% (see Fig. 3).

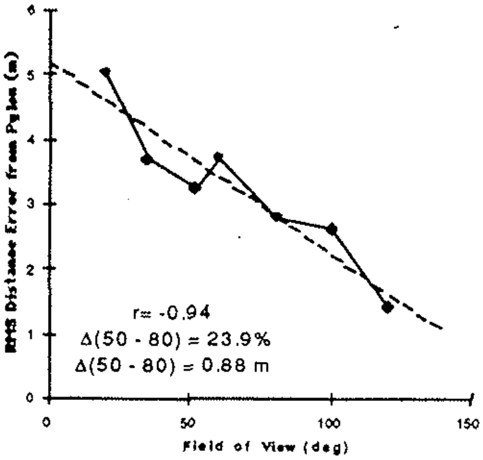

Figure 1. RMS Position Error on Pirouette

The slalom did not have a predefined correct path. The only requirement was to pass through all the gates in sequence. The variable which appeared most promising was the proportion of good runs, where a good run was one in which the aircraft passed through all the gates in sequence. This variable showed a marked increase with FOV (see Fig. 4), but the effect was not reliable owing to the small number of good runs obtained (fewer than 10%).

Subjective

A two-way ANOVA was performed on the pilot workload subjective ratings. The sensor location factor had two levels (aircraft nose and pilot's eyes) and the FOV size factor had four levels (20°, 35°, 60°, and 100°).

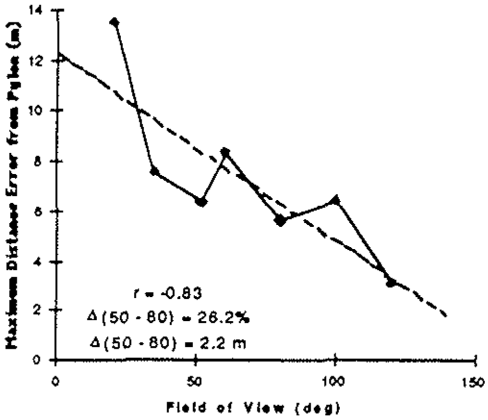

Figure 2. Maximum Position Error on Pirouette

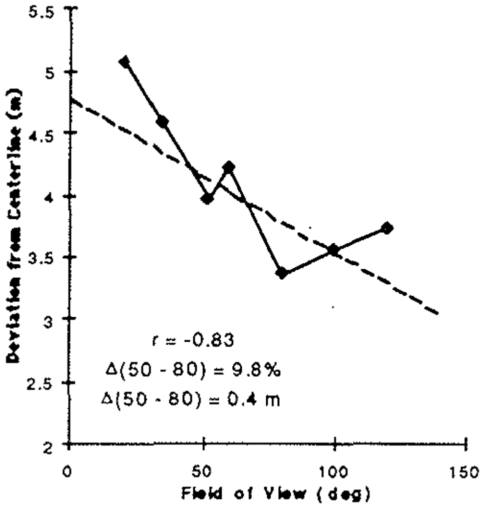

Figure 3. Mean Deviation From Centerline on Gulch

Sensor Location Effects. The main effect of sensor location was not reliable for any of the precision maneuvers or the contour course.

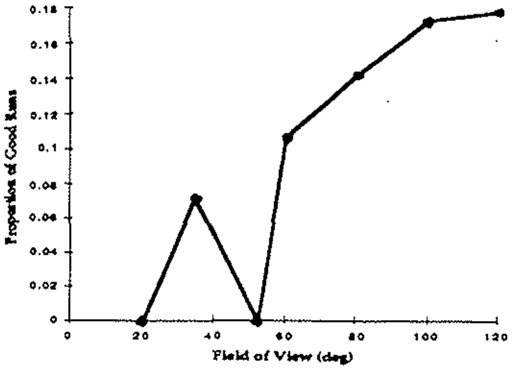

Figure 4. Proportion of Good Runs on Slalom

FOV Size Effects. The main effect of FOV size was reliable for all of the precision maneuvers and the contour course. Pilots workload ratings, collapsed across all maneuvers and sensor location, were highest in the 20° condition and lowest in the 100° condition (see Fig. 5). This suggests that as FOV size decreases, pilots report a reliably higher flight task performance workload.

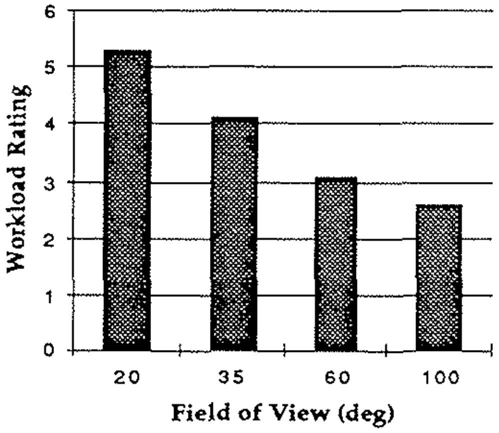

Figure 5. Subjective Rating of Overall Workload

There was no reliable interaction between sensor location and FOV for all of the precision maneuvers and the contour course.

The FOV and sensor location mean acceptability ratings were collapsed across all maneuvers and sensor location. The acceptability ratings closely corresponded to the workload ratings where the 20° FOV (highest workload rating) was rated as the least acceptable. The 100° FOV (lowest workload rating) was rated as the most acceptable (see Fig. 6).

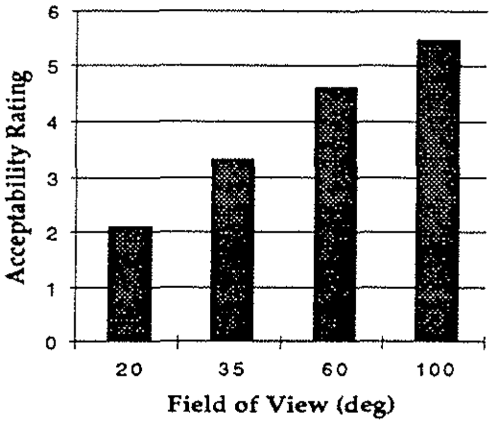

Figure 6. Subjective Rating of Acceptability

Descriptive statistics were performed on the control and special case conditions. The overall workload and mean acceptability ratings, collapsed across maneuvers and sensor location, were nearly identical for control condition's 1 and 2 (see Fig. 7). Overall workload was rated as low and the acceptability was rated as high. In the special case conditions, workload and acceptability was rated as moderate for the 52° x 35° FOV, and as low workload and high acceptability for the 80° x 40° FOV (see Fig. 8).

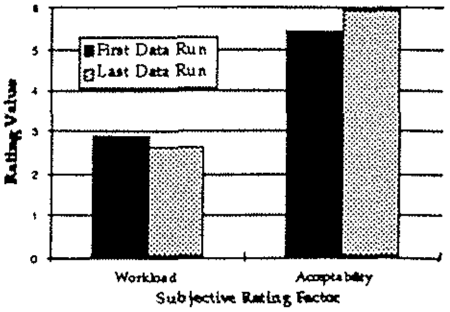

Figure 7. Comparison of First and Last Day Subjective Ratings for 120° FOV

Conclusions

Conclusions

Summarizing the objective data, we found three variables that showed reliable effects of varying FOV on performance of two flight tasks. Performance benefits derived from increasing FOV from 50° to 80° varied from just under 10% to over 25%. In addition, pilot workload ratings showed a significant effect of FOV size on flight performance for all the maneuvers. Workload ratings were significantly higher in the 20° FOV condition and lower in the 100° condition.

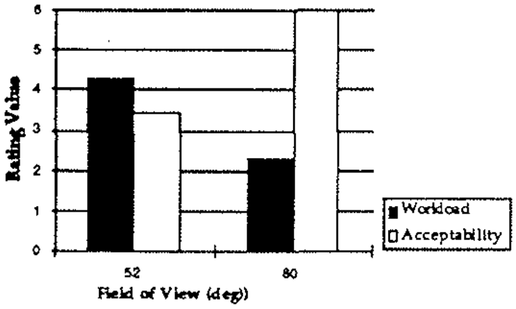

Figure 8. Comparison of 52° and 80° Special Cases

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Appendix A

Precision Maneuver Instructions

Hover: The helicopter will start from a stabilized hover above the Initial Position (IP) at a hover altitude of 15 ft. The helicopter will fly forward (North up) at 6-10 knots until the break-off point is reached. At the break-off point the helicopter will fly 45° to the right at a speed of 6-10 knots and come to a hover over the hover point. Once the helicopter is in a stable 15 ft. hover, hold the hover for 15 sec.

Hover Turn: From a stabilized hover (altitude = 15 ft) the helicopter will perform a complete 180° first to the right and then back to the left. The helicopter should be stabilized briefly at the end of each turn.

Pirouette: The maneuver will be initiated from a stabilized hover (altitude = 15 ft) over the IP located 100 ft from a reference point at the center of circle. The helicopter will fly at a lateral translation (nominal speed of 8 knots) around the circle, keeping the nose of the helicopter pointed at the reference point at the center of the circle and the circumference of the circle under the center of the helicopter. The maneuver will be terminated with a stabilized hover (5 sec.) over the starting point (the hover must be achieved within 5 sec of returning to the starting point). The maneuver must be completed within 45 sec.

Acceleration/Deceleration: Starting from a stabilized hover at the IP (altitude = 30 ft), the helicopter will rapidly accelerate forward to an airspeed of 50 knots (maintaining an altitude below 50 ft). Upon reaching 50 knots, the helicopter will rapidly decelerate to a hover at or less than 20 ft. beyond the reference line (once the hover has been initiated, the hover is held for 5 sec).

Sidestep: Starting from a stabilized hover over the IP (hover altitude = 15 ft) with the longitudinal axis of the helicopter oriented 90° to a reference line marked on the ground (cones), a rapid translation is initiated towards the end point. Once the end point on the reference line has been reached, a hover must be established within 5 sec and maintained for 5 sec. The maneuver is immediately repeated in the opposite direction.

Slalom: Starting from the IP, the maneuver is initiated in level unaccelerated flight (60 knots) with the helicopter lined up with the centerline. Beginning with a turn to the right, a series of smooth turns are performed at 500 ft intervals. The turns are performed at a minimum of 50 ft from the centerline with a maximum lateral error of 50 ft. (marked by cones). The maneuver is accomplished at an altitude of 50 ft. An airspeed of 60 knots must be maintained throughout the slalom.

Bob-up/down: From a stabilized hover of 10 ft, the helicopter must bob-up to a 50 ft reference altitude in order to observe a reference point located 100 m from the helicopter (a vertical pole located halfway between the IP and the reference point is used as a sighting mechanism). The helicopter hovers at the 50 ft reference altitude for 5 sec and then bobs-down and re-establishes the 10 ft stable hover.

Recovery to Hover: The maneuver is initiated at an altitude of 25 ft. The crew station (helicopter) is frozen and re-positioned while a perturbation is input (4 different perturbations vectors = 40 knots are available). The controls/visuals are returned to the pilot, the crew station is unfrozen, and the pilot attempts to recover to a hover at some distance "x" from the IP. The hover is maintained for 15 seconds.

Gulch: Starting from the IP, the helicopter flies the course at a constant level altitude (30 ft) and airspeed (40 knots). The helicopter flies between pairs of poles that form an ever-narrowing path. The maneuver is complete when the helicopter has either left the course or passed through the last pair of poles.

Contour Course: Starting from the IP, the helicopter flies the 25 kilometer course at approximately 50 ft. (altitude) and 50 knots (airspeed). The helicopter is flown directly over pairs of tanks that serve as visual waypoints (the tanks turrets point in the direction of the next pair of tanks). The course is complete when the helicopter passes the last waypoint.