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Field Of View Effects Upon A Simulated Flight And Target Acquisition Task

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ABSTRACT

Pilot flight performance and target acquisition were evaluated for 40 degree and 100 degree fields of view in the Synthetic Immersion Research Environment at the Air Force Research Laboratory. The facility consists of an F-16 like cockpit mockup and a 40-foot diameter dome display. The simulation environment includes textured ground and sky features with embedded ground targets. Daytime simulators of night vision goggles were worn by the pilots to limit field of view. Pilots were able to acquire and designate 16 percent more targets with the 100 degree field of view than with the 40 degree field of view. Pilot flight performance was not found to be affected by field of view.

INTRODUCTION

Current generations of night vision goggles (NVGs) are limited to a 40 degree field of view. Pilots have described the use of these goggles as trying to fly while looking through a straw. The Air Force Research Laboratory is currently developing a new night vision goggle, called the Panoramic Night Vision Goggle, which will provide a 100 degree field of view. In order to significantly increase the field of view of night vision goggles, a novel approach was required. This approach uses four image intensifier tubes instead of the usual two to produce a 100 degree wide field of view.

NVGs with fields of view ranging from 30° (GEC-Marconi Avionics' Cat's Eyes NVGs) to 45° (GEC-Marconi Avionics' NITE-OP and NITE-Bird NVGs) have been used in military aviation for more than 20 years. The vast majority of NVGs in use today (AN/AVS-6 and AN/AVS-9) provide a 40° FOV. An extensive survey of military (U.S. Air Force) NVG users conducted during 1992 and 1993 revealed that increased FOV was the number one enhancement most desired by aircrew members followed closely by resolution.[1] This was a major motivating factor for the development of an enhanced NVG capability. While pilot acceptance of the panoramic goggle prototype is extremely positive, no objective performance data are yet available.

BACKGROUND

While current operational flight testing of the PNVG at Nellis Air Force Base has yielded very positive subjective evaluation of the advantages of increased field of view, no objective evaluation of pilot performance is yet available. Several other experimenters have reported improved operator performance as a function of increased field of view. Those most applicable are described below.

Szoboszlay et al. conducted an experiment in which a series of prescribed low altitude maneuvers were performed by eleven

US pilots and 4 UK pilots with an instrumented rotorcraft.[2,3] The pilots wore a specially constructed helmet visor which limited the field of view. Horizontal limits were: unrestricted, 100, 80, 60, 40 and 20 degrees. The vertical limit remained constant at 40 degrees, and all except the 20 degree field of view had a 40 degree overlap._The aircraft flight path was measured with a laser tracker. On board flight data were recorded giving the position of the aircraft in three dimensions, radar altitude and attitude.

Standard statistical comparisons were made of the task performance at each field of view compared to the performance at unrestricted field of view. Only for the precision landing and hovering turn and the entire bob-up, did fields of view greater than 40 degrees show significant differences compared to the performance with unrestricted field of view. Data for U.S. pilots were analyzed for each maneuver to determine the limit beyond which increasing field of view did not result in increased performance. There was considerable variation due to maneuver with range of 40 to 98 degrees.

Pilots flying with restricted field of view often thought they were flying the aircraft better than they actually were. At 60 degrees field of view, one pilot who was very experienced in flying AH-1S aircraft and NVGs stated that his poor situational awareness and performance "was very insidious" since he felt that he was performing much better than he actually was. Nearly all pilots missed seeing the RPM warning indicator at the top of the instrument panel. Several pilots commented that with restricted field of view they could not see multiple cues at the same time and had to switch between cues. This required more head movement and a different scan technique. Some commented that a large amount of head movement caused problems in controlling the aircraft as well as some disorientation.

Kenyon et al. studied field of view effects in the laboratory for a critical tracking task.[4] The tracking task required stabilization of the roll motion of a visual scene driven by an unstable first order plant. The fields of view studied were in the range of 10 - 120 degrees. A dedicated graphics workstation read and stored the subject's control input and generated the out-the-window scene which was displayed on a 19-inch color monitor. The visual conditions were produced by having the subject view the face of the CRT through the Expanded Field Display, an optical system that expands the CRT image over a 120 degree field of view. Particular fields of view were created by cutting circular holes in black matte paper. These masks were inserted into the viewing system. Five male subjects participated in this experiment. The primary measure was effective time delay. A transition time constant was also calculated as an indicator of task difficulty.

The subjects' performance was worst at the 10 degree field of view. The most improvement occurred up to the 40 degree field of view. The best performance occurred at 80 or 100 degree field of view. The subjects reported that the task was easiest at the 80 degree field of view. The authors suggested that increasing the field of view from 40 to 80 degrees, while improving performance only slightly, greatly reduced the subjects' workload.

Wells et al. studied field of view effects upon a target acquisition and replacement task combined with a tracking task.[5] The targets were arrowhead shaped, 2.2 degree high and wide within a gaming area 120 degrees left and right and 90 degrees upwards from straight ahead. The targets were viewed in combination with a terrain scene or a blank background. There were two search conditions: slow search up to three minutes to find and memorize target positions, and search and remove as fast as possible.

The subjects were required to visually acquire, remember the location of, monitor (for threat mode indicated by shape change), and shoot 3 or 6 objects. The secondary tracking task required the subject to keep an inverted "T" straight and level on the display. The field of view was 120x60 degrees for terrain and the tracking task. Fields of view were 20x20, 45x42.5, 60x50, 90x60 and 120x60 (azimuth x elevation) for targets.

This experimental set-up simulated viewing the output from a head-steered sensor on a see-through helmet-mounted display. Two helmet-mounted displays were used with a combined maximum field of view of 120x80 with a 40 degree binocular overlap. The position of the helmet was measured in 6 axes with an electromagnetic helmet position tracker; this information was used to present space-stabilized images on the displays. A computer generated stroke-drawn world of 4 pi steradians at optical infinity updated at 20Hz. A head-stabilized reticle cross was always present in the center of the field of view. The subjects were 10 paid volunteers. The number of objects hit, mean time threatened, replacement error and RMS tracking error were recorded.

For the shoot and replace task alone, there was a significant interaction between target density and field of view and a performance decrement only at the 20 degree field of view for the higher target density. Data were similar under dual task conditions. However, there was a significant effect of field of view upon tracking error. These data show a trend of decreasing error with increasing field of view up through 90 degrees. The authors concluded that the decrement in secondary task performance with decreasing fields of view suggests that the subjects had to allocate more resources to the primary task when working with smaller fields of view. The increase in tracking error with the small fields of view occurred despite longer allowed search times for the conditions with smaller fields of view.

While all of the above studies show some advantages of fields of view larger than 40 degrees, we were particularly interested in the comparison of 40 degrees and 100 degrees which represent NVGs currently in use and the PNVG respectively. The pilot study reported herein evaluated these two fields of view for performance of a primary low level flight task with secondary target acquisition task.

METHOD

Flight performance and target acquisition were evaluated for two pilots in the Synthetic Immersion Research Environment at the Air Force Research Laboratory . The facility, which is shown in Figure 1, consists of an F-16 like cockpit mockup and a 40-foot diameter dome display. Flight controls available to the pilot included a sidestick controller, throttle, and rudder pedals. A head up display (HUD) and three head down displays (HDDs) provided basic flight information, navigation instrumentation and radar warning receiver (RWR) scope. The simulation environment included textured ground and sky features. An out-the-window visual scene was displayed on the surface of the dome. The terrain data used for the simulation was a 50 by 60 nautical mile area near Albuquerque, New Mexico. Embedded in the terrain database were numerous stationary SCUD-like targets. A head-coupled target designator was also displayed on the surface of the dome.

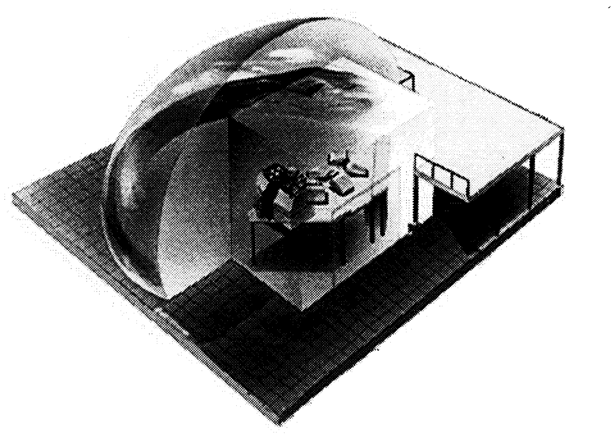

Figure 1. Synthesized Immersion Research Environment

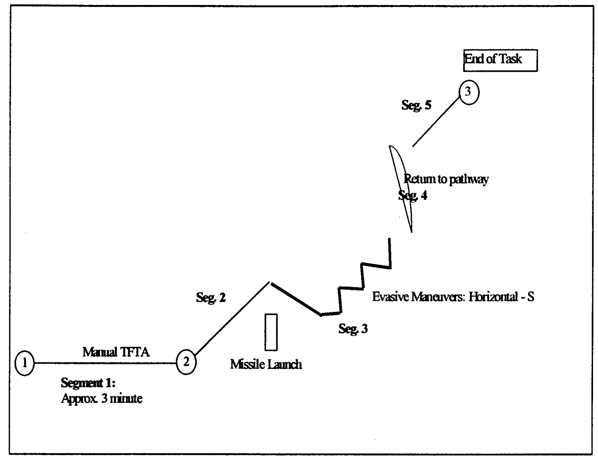

Figure 2. Flight path graphic.

Forty eight unique flight paths were predefined within the 50 by 60 nautical mile gaming area. Each flight path was defined by 3 points: (1) a start point, (2) a turn point and (3) an end of task point. A flight path graphic is shown in Figure 2. This effectively divided the flight path into two segments. The mission was a low level ingress with intent to deliver a weapon; however, the weapon delivery segment was not included in the simulation. The mission simulation began with the pilot's ownship on course at approximately 500 feet above ground level (AGL). The pilots were instructed to maintain an altitude of 500 feet AGL and airspeed of 350 knots. At a variable time early in the second segment, a missile launch event took place. The pilot was required to perform evasive maneuvers and release chaff in response to the missile launch event. As soon as the missile was no longer a threat, the pilot was required to recover the aircraft to the preplanned flight path. Several parameters of the pilot's performance were scored. These included airspeed, altitude, maneuver to avoid missile and frequency of chaff release. If the total score was not within acceptable parameters, the mission was aborted.

In addition to the flight task, the pilots were required to scan the surrounding terrain and designate as many of the ground targets as possible. This was accomplished by moving the head-coupled target designator over the target and pulling the trigger on the sidestick controller. The pilots were instructed to treat the precision navigation flight task as their primary task and the targeting task as a secondary task.

Daytime simulators of night vision goggles were worn by the pilots to limit field of view. Two fields of view were evaluated; these were 40 degrees and 100 degrees. The 40 degree field of view represents the currently fielded night vision goggles while the 100 degree field of view represents the newly developed PNVG.

Prior to the data collection trials, the pilots were given a familiarization briefing of the cockpit and the mission to be flown. They were then allowed to fly several trials with unlimited field of view until they felt comfortable with the task to be performed. They then flew three practice trials with the 100 degree and 40 degree field of view NVG simulators. If any trial was aborted due to unacceptable flight performance or crashing into terrain, it was repeated.

For the data collection, the pilots flew each of three distinct flight paths four times - twice with the 40 degree field of view and twice with the 100 degree field of view – for a total of twelve trials. These three flight paths were different from those flown by the pilots during the practice trials. While a large number of targets are in the vicinity of the flight path, many are obscured by terrain. The number of targets actually visible to the pilot was dependent upon the altitude and actual flight path of the aircraft; generally between 40 and 60 targets were visible at some time during each trial. Each trial took approximately four to five minutes.

RESULTS

Analyses of variances were conducted to examine the effects of field of view upon several flight parameters including the percent of time above 500 feet AGL, mean altitude (feet), standard deviation of altitude (feet) and RMS lateral course error. None of these parameters were found to differ significantly as a function of field of view. The number of target designations was found to differ significantly as a function of field of view. The mean number of target designations for the 40 degree field of view was 24.5 while that for the 100 degree field of view was 28.5. The targets actually visible to the pilot during each trial were counted and the percentage of these targets that were designated was calculated. The pilots designated 48.7 percent of the visible targets while wearing the 40 degree field of view simulator and 60.2 percent while wearing the 100 degree field of view simulator. This difference was not statistically significant.

DISCUSSION

The lack of significant effects upon any of the flight performance parameters indicates that pilots were able to maintain an acceptable level of flight performance with either the 40 or 100 degree field of view. The significant effect of field of view upon number of target designations indicates that pilots were able to increase target acquisition performance while maintaining flight performance. The 100 degree field of view resulted in a 16 percent increase in the number of target designations over that with the 40 degree field of view. Pilots indicated that with the wider field of view they felt more comfortable in looking away from the flight path in search of targets.

The current data represents only two pilots. Certainly data must be collected for several more pilots and further analyses conducted. The lack of statistical significance for the percent of visible targets designated was probably due to the small sample size. Also of interest for future experimentation is the effect of increased field of view in enabling the pilot to detect airborne targets.

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