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DEVELOPMENT OF A PROTOTYPE EXPERIMENTAL PLAN TO EVALUATE STABILIZED OPTICAL VIEWING DEVICES: I. INFLIGHT MEASURES OF VISUAL ACUITY

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Joint Report

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An improved M-76 stabilized viewing device was tested in a scout helicopter flight scenario. Target acquisition performance was significantly correlated with the airsickness ratings of an onboard experimenter. Since there was no significant difference between the magnitude of the symptoms observed when the device was stabilized and the magnitude when caged, the stabilization feature proper could not be identified as a problem source. Parts II and III of the report (in preparation) will deal with inflight measures of airsickness potential

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SUMMARY

An improved XM-76 stabilized viewing device was tested in a scout helicopter flight scenario. Target acquisition performance was significantly correlated with the airsickness ratings of an onboard experimenter. Since there was no significant difference between the magnitude of the symptoms observed when the device was stabilized and the magnitude when caged, the stabilization feature proper could not be identified as a problem source. Parts II and III of the report (in preparation) will deal with inflight measures of airsickness potential and the laboratory evaluation of individual susceptibility to airsickness respectively.

ROBERT W. BAILEY
COL, MSC
Commanding

INTRODUCTION

Recently the Naval Aerospace Medical Research Laboratory (NAMRL) was asked[1] to evaluate the XM-76 gyrostabilized monocular viewing device in response to a reported nausea problem during air-to-ground observation. At about the same time, the U.S. Army Aviation Systems Command was considering this type of device as a target acquisition aid in the product-improved scout helicopter, and requested[2] the U.S. Army Aeromedical Research Laboratory (USAARL) to "determine if crew members of a helicopter will experience vertigo or airsickness using optical devices to view terrain." Although previous studies of the XM-76 have been conducted[3,4,5,6,7,8], they were in the main subjective evaluations of target acquisition and did not directly address the nausea problem.

As a result of this mutual Army/Navy interest in the same operational problem, and because of the complementary facilities and experiences of the two laboratories, it was decided to develop a prototype procedure for evaluating viewing devices of this type. Several features of the prototype procedure were agreed upon. First, it was considered necessary to have measures of inflight visual performance as an indication of the extent to which the viewing devices were being used effectively. Some visual tasks are nauseogenic during motion, but it is fairly simple to avoid nausea by closing the eyes. For this reason, a measure of visual performance was deemed necessary. Moreover, the use of the inflight task provided a measure of the specific performance of interest. Second, it was considered desirable to have a standard set of flight maneuvers during the visual performance. Third, since the number of subjects available to participate in such experiments is limited, it was considered desirable to assess visual and vestibular functions of participating subjects, with a view toward establishing that the group would represent a normal range of reactivity to motion. From USAARL/NAMRL working conferences, specific objectives planned were development of a quantitative measure of air-to-ground visual acuity over an instrumented target range; selection of an inflight experimental protocol for the viewing task proper that required the same amount of visual effort from each participating subject; selection of a series of repeatable flight maneuvers representative of the operational situation but which, in themselves, would not be overly provocative of motion sickness; development of a method for the airborne rating of the airsickness reactions of the subjects while using the viewing devices; and development of a laboratory-based series of visual/vestibular tests to evaluate the visual and vestibular function and motion sickness susceptibility of the group of participating subjects.

In a preliminary effort to meet these objectives, a joint USAARL/NAMRL study was developed in which a flight phase would be conducted at the Army facility followed by a laboratory evaluation of motion sickness susceptibility at the Navy facility. In flight, the subject would be tasked with target identifications while being exposed to a series of flight maneuvers in the UH-1 helicopter. Concurrently, an onboard observer would rate selected airsickness symptoms that might arise during the course of the flight. A total of three flights would be required for each subject. In the first flight, which served primarily as an indoctrination run, the subject would perform the target identification task without the assistance of the viewing device. For the second flight, half of the subjects would use the XM-76 viewing device with its internal stabilization system caged (no stabilization), and half would use the device in its normal stabilized operating mode. The order for the two groups of subjects would be reversed on the third flight. With this protocol, the study had the dual objective of measuring the improvement in visual acuity afforded by the stabilization feature of the XM-76, and determining the effect of this stabilization on the reported nausea problem.

This report deals with the over-all results of the flight phase of the experiment with particular emphasis placed on the visual acuity aspects. A second report[17] is in preparation that will detail the results of the inflight ratings of airsickness symptoms and the post-flight questionnaires completed by the subjects. The results of the laboratory tests conducted on each of the subjects at NAMRL will be summarized in a third report[18]. It is expected that this preliminary study, in conjunction with related follow-up studies on different viewing devices, will lead to the development of the desired prototype experimental plan.

METHODOLOGY AND APPARATUS

The XM-76 (redesignated Dynalens model MS-023) manufactured by Dynascience Corporation is a monocular viewing device with a zoom capability. The optical image is stabilized by a gyroscopically controlled, variable wedge, fluid prism. It is powered by either an attached battery cassette or by 15-33V DC power. In this study 28V DC power from the aircraft was used because the mission length exceeded the charge of the battery cassette. The device weighs 40 oz.[10].

All airborne observations were made from the observer's seat (left front) of a UH-1H helicopter between 1000 hrs and 1430 hrs and only on days in which the visiblity was greater than ten kilometers.

Twenty-nine subjects were used. All were commissioned officers in the Army. Two had graduated from the rotary wing flight training program, one had completed 94 hours in the rotary wing program, and the remainder were entering students. All subjects had previous flight experience either as civilian private pilots or as passengers in Army tactical operations.

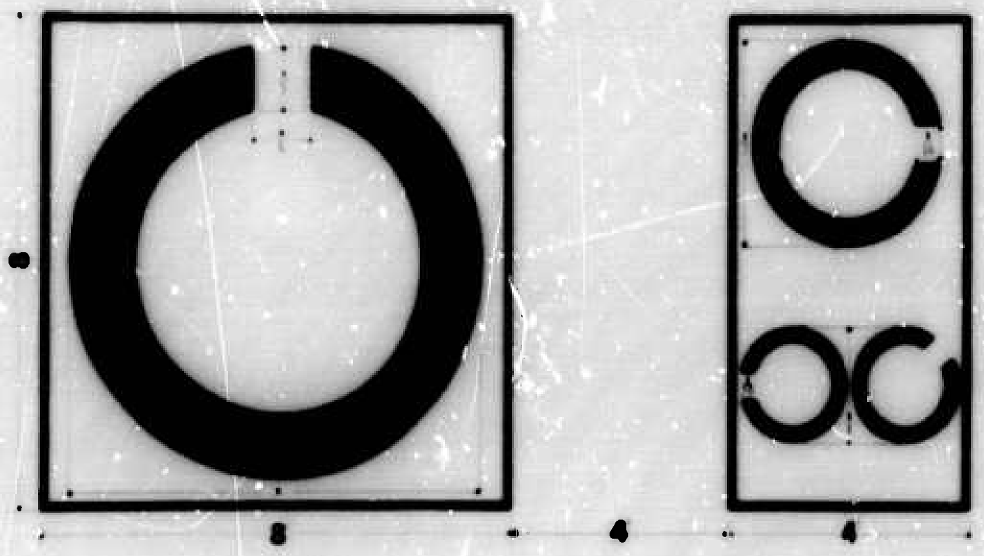
The test course was nine kilometers in length over slightly rolling farm and woodlands.

Each subject flew one flight on each of three separate days. A flight consisted of five passes at the targets. Passes one and five were flown straight to the targets. Passes two and four were "pop-up" maneuvers in which the aircraft would fly below the line of sight to the targets then increase altitude until the target area was just visible and repeat this cycle as he approached the targets. Pass three consisted of continuous "S" turns with heading changes 30 to 40 degrees either side of the center-line. All passes were flown at 55 knots to remain out of the dead man's portion of the engine failure envelope.

The first day's flight was made using only the unaided eye. On the second day, in order to prevent biased results from learning effects, half of the subjects used the XM-76 in a caged mode (as a control) and half used it as a stabilized viewing device. Their roles were then reversed on the third day. The subjects were not told which mode was being used. In both modes, the XM-76 was a 7 power monocular viewing device. Although the XM-76 has a zoom capability from 1.5X to 12X, it was used in the 7X mode throughout to prevent confounding zoom effects with the stabilization effects which we were studying.

The subject's first task on each pass was to locate the target area with the unaided eye before viewing through the XM-76 (except on the first day when all sighting was with naked eye only). He then reported when he could detect the target panels followed by when he could distinguish that there were two separate panels. The targets on the panels were Landolt C's as shown in Figure 1. Target #1 was twice as large as #2 which, in turn, was twice the size of target #3. The gap in the C, which could be in any one of eight possible positions, was controlled by ground personnel at the target sites. The subject's final task was to report the gap position. A forced choice procedure was used. The subject was repeatedly requested to "guess" the position of the gap as soon as he reported that he could detect the two panels. The criterion for correct response was two responses of the correct orientation of the C in succession. The subject then diverted his attention to the next smaller target, and the procedure was repeated. This continued until the aircraft was within 1000 meters of the target at which time observations were terminated. The orientation of the C's were randomly selected and changed after each pass.

TARGET DESIGN & DIMENSIONS



TARGETS ROTATABLE AND WERE POSITIONED IN ONE OF 4 POSITIONS X=1.754M (5.73FT)

Before each flight and after each pass at the target, an onboard observer evaluated and check list scored each subject relative to selected airsickness symptoms including pallor, sweating, facial expression, and inflight anxiety. A second observer performed a similar evaluation immediately following the flight. These observer ratings were totaled and the resultant sum used as an over-all rating of airsickness susceptibility on an individual subject basis. At the end of the second and third flights, the subjects were required to complete a questionnaire which dealt with their subjective evaluation of the performance of the device and any observed airsickness reactions.

Observation distances were computed using the Aeromedical Research Laboratory's radio-radio range system on board the aircraft[16]. The system consists of four ground transmitters located on the corners of a 10 mile square giving 100 square miles of ranging area. Distances for this study were accurate to 50 meters through the 9000 meter course.

RESULTS

TABLE I

SUMMARY OF INFLIGHT AIRSICKNESS SYMPTOMS RECORDED BY THE ONBOARD EXPERIMENTERS FOR THE THREE VIEWING CONDITIONS OF THE STUDY.
Statistical summary for the entire subject group (n=29)

	Unaided eye (no viewing device)	XM-76 (Caged)	XM-76 (Stabilized)
Group mean	40.6	61.1	55.2
Standard deviation	5.9	20.0	15.5
Standard error	1.1	3.7	2.9

The group mean, standard deviation, and standard error of the mean of the airsickness evaluation made by the two observers are listed in Table I for the three different flight conditions. Figures 2, 3, and 4 show distances for panel detection, distinguishing two separate panels, and correct identification of the Landolt C positions, as a function of the type of flight maneuver, for each of the three modes (unaided eye, XM-76 caged, and XM-76 stabilized). It is interesting that in all of these figures, the subjects' performance with the more demanding task of detecting the orientation of the Landolt C was equivalent or slightly better on the pop-up maneuvers as on the straight and level passes. This could possibly be attributed to the subjects' awareness of the limited viewing time possible with the pop-up maneuvers. With the relatively unlimited viewing time in the straight and level passes, the subjects could have been more reticent to "guess" until they were more positive of their answers.

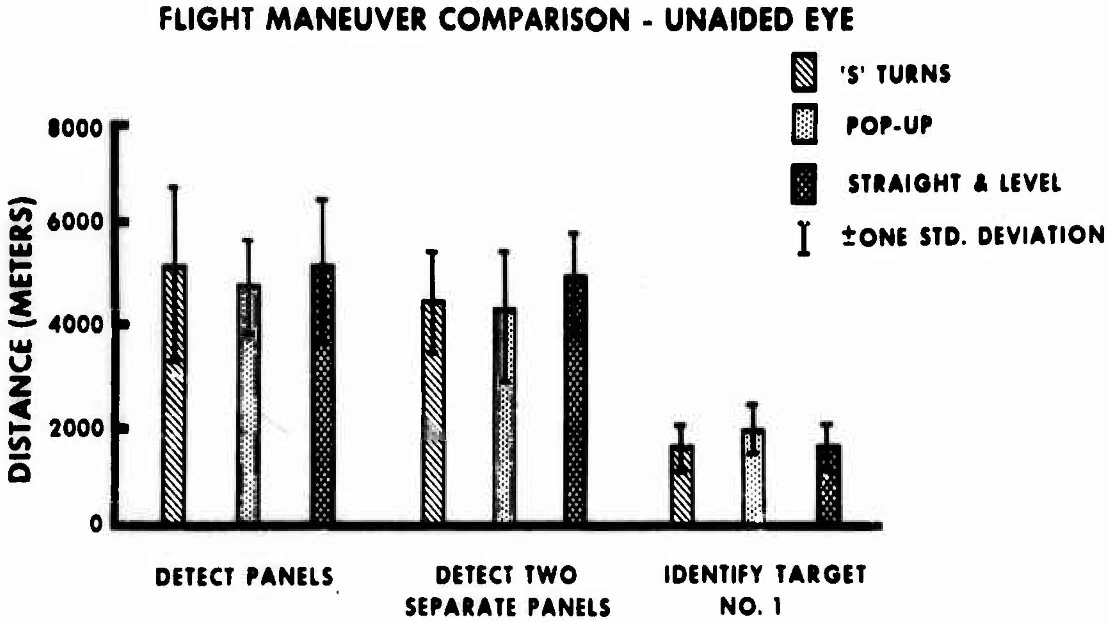


FIGURE 2.

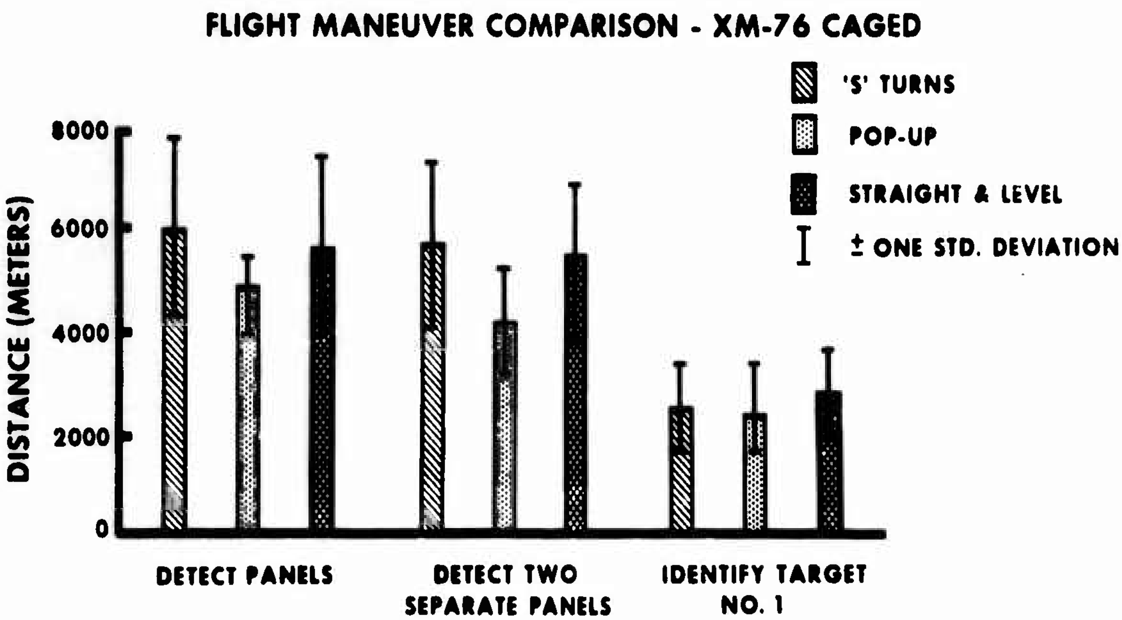


FIGURE 3.

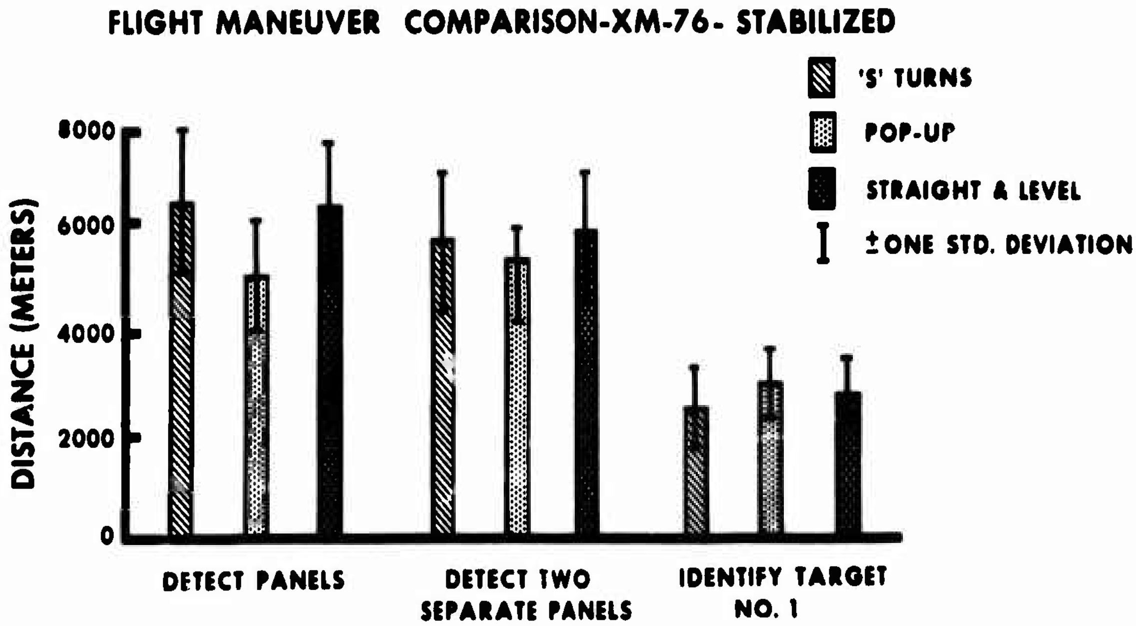


FIGURE 4.

Figure 5 shows a comparison of the mode of viewing, using an average of the five passes, as a function of the device used. It can be seen in this figure that the observation distances were greater for all detection tasks when the subjects used the XM-76 in the stabilized mode. The angular resolutions shown in Table II were calculated from the observations distances and the size of the target panels, distance between the panels, and the size of the Landolt C's.

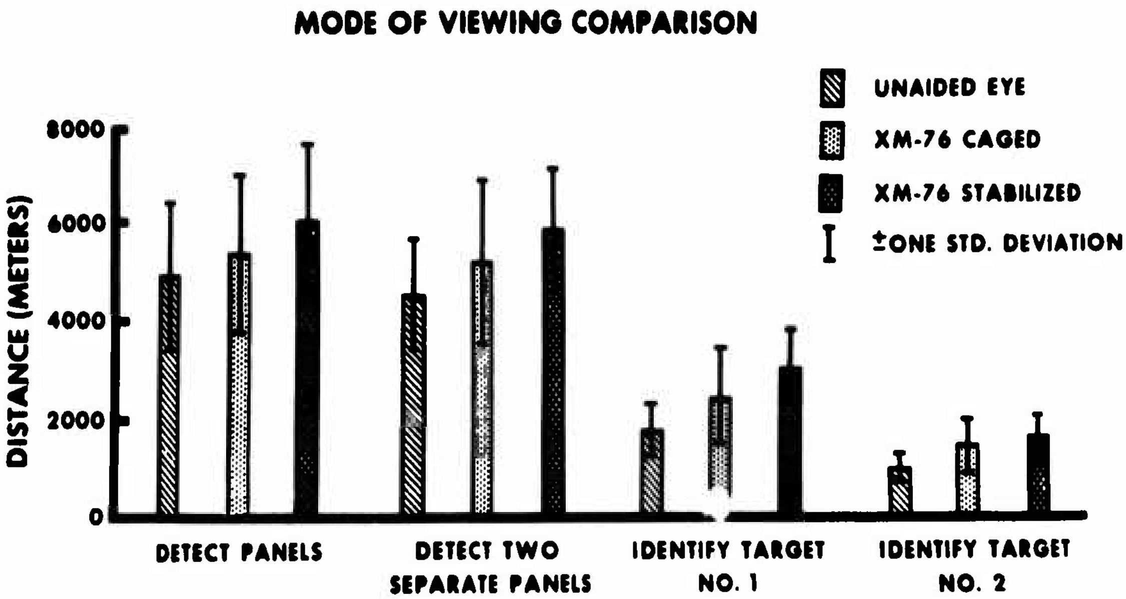


FIGURE 5.

TABLE II

MEAN ANGULAR SUBTENSE (MIN. OF ARC) OF TARGETS AT DETECTION/IDENTIFICATION

	DETECT TARGET ARRAY*	DETECT TWO TARGETS**	IDENTIFY *** TARGET #1	IDENTIFY *** TARGET #2	IDENTIFY *** TARGET #3
UNAIDED EYE	3.4	0.94	0.70	0.65	---
XM-76 CAGED (7X MAGNIFICATION)	3.06	0.81	0.50	0.43	0.29
XM-76 STABILIZED (7X MAGNIFICATION)	2.79	0.73	0.40	0.38	0.31

* Based on 16 ft. length of the two target panels and the 4 ft. separation between them. (See Fig)

** Based on four ft. separation between the two target panels.

*** Based on gap size of the Landolt C's.

DISCUSSION

Referring to Table I, the group mean of 40.6 for the airsickness symptoms mainifested during the first flight when the targets were viewed with the unaided eye represents the reference baseline for this subject group. This score indicates that the subject group was relatively undisturbed by the viewing task during the five-pass flight. As indicated by the group mean of 61.1 for the caged XM-76 flight and 55.2 for the stabilized XM-76 task, airsickness symptoms rose considerably when the visual task involved using an optical viewing device. A t-test comparison of the individual means for the three test conditions indicates a statistical difference (pL.01) for both the caged XM-76 flight relative to the unaided eye flight ($t = 5.29$) and the stabilized XM-76 flight ($t = 4.74$). The difference between the stabilized and caged XM-76 flights was not significant ($t = 1.25$). In this respect, these data indicate that the stabilization feature proper of the XM-76 did not in itself account for the observed rise in airsickness symptoms in that a comparable rise occurred when the device optics were not stabilized. There was a low but statistically significant correlation between airsickness rating data ($r_s = 0.40$, Spearman Rank-Order Correlation) and the subjects target identification performance while using the XM-76 in the stabilized mode. The correlation was not significant ($r_s = 0.30$, pL .10) between target identification and results of the subjects' self-rating questionnaires. Details pertaining to these flights and questionnaire ratings of airsickness will be outlined in a separate following report[17]. A third report[18] will summarize the laboratory testing phase of the study which was directed toward gaining an over-all evaluation of vestibular function, visual function, and motion sickness susceptibility rating of the subject group. Preliminary analysis of the results of these laboratory tests indicate that the subject group could be considered average or slightly above average in motion sickness susceptibility, although this is subject to some interpretation because of the special conditions under which the tests were carried out[18].

In 87 flights including 435 target passes there were no cases of nausea to the point of vomiting. One subject began sweating profusely on his second pass while using the XM-76 in the control (caged) mode, but was able to complete his five passes. (He had

60 previous flight hours including a private license.) Terminating each pass at approximately 1000 meters probably helped avoid nausea because the relative motion of the aircraft and target was slight at distances greater than this.

The static Snellen visual acuity threshold on normal observers is 20/15 to 20/20. All of the subjects were within this range. An acuity of 20/15 is represented by a gap size on a Landolt C of 0.75 minute of arc. Table II shows the mean angular subtense for the unaided eye in flight to be quite near the static threshold. (Identification of Target #1)

Visual resolution or acuity is a rather complex measure. Many parameters (e.g. angular size, contrast, color, observation time, figure-ground visual complexity, luminance conditions, etc.) can have a profound effect on the performance results. The targets used in this study consisted of black Landolt C's of standard dimensional ratios on a white background yielding a contrast measured at the targets of 0.86. Obviously, when viewing through optical instruments, the contrast and image fidelity will be altered. Such a change is apparent in Figure 5 and Table II. As shown in Figure 5, the observation distance to detect the gap in the larger target with unaided vision was 1697 m while with the stabilized XM-76 the distance was 2960 m. Table II shows that the corresponding target angular subtenses for these distances were 0.70 minutes with the unaided eye and 0.40 with the stabilized XM-76. Therefore, the gain in performance was less than a factor of 2 (instead of 7) with the 7X magnification used in the XM-76. Such a non-linear gain can be attributed in part to a loss in contrast and the degraded quality of the image presented to the eye. These results can be used as an example of any discussion of performance and magnification. There is no simple relationship between optical magnification and visual observation distances. Some compromise in image quality is always necessary with optical viewing devices. The magnitude of the trade-off will depend upon the quality of the optics in each individual instrument.

Figure 5 shows the increased observation distances possible with the XM-76 when used in the stabilized mode compared to those found with the caged mode. While the differences were slight, they were statistically significant ($p = 0.01$, Wilcoxin Matched Pairs, Signed Ranks Test).

In a recent comparison using other stabilization devices with the same targets as in this study, four of five of the devices produced target acquisition distances which were at least twice as great as those found in this study with the XM-76[19]. However, experienced observers served as subjects in this study. Again, there was no nausea in this scenario.

The Combat Developments Experimentation Command (CDEC) experiment 43.6[7] contained a resolution section in which the XM-76 was compared with an XM-26 and an XM-27 (other target acquisition sights). The resolution of the XM-76 was 2 1/2 times poorer than the other two. The CDEC mean resolution for the XM-76 was 2.8 minutes of arc, the same as our finding. (See Table II. The angular subtense of target #1 with the XM-76 stabilized is (0.4) (7X) = 2.8 min. of arc subtended at the eye.)

CONCLUSIONS

The use of the denoted optical device under the flight regimen selected for this study did not result in a significant airsickness problem. It was observed, however, that the incidence of airsickness symptoms rose when the subjects performed their assigned visual task with the device rather than the unaided eye. Since there was no significant difference between the magnitude of the symptoms observed when the device was stabilized and the magnitude when caged, the stabilization feature proper could not be identified as a problem source. The data also indicate that target acquisition performance was significantly correlated with the airsickness ratings of the on-board experimenter. Correlation with the postflight self-rating questionnaire, though in the same direction, was not significant. The direction of the correlation, assuming it would be sustained in repeat testing, suggests that individuals who maintain good visual performance tend to show fewer signs of sickness or conversely, those who show signs of sickness tended to perform below average. In this experiment, because very little airsickness was encountered, there was little opportunity for potential relations between airsickness and visual performance to become manifest.

RECOMMENDATIONS

1. Stabilized viewing devices should be pursued as target acquisition aids in the scout helicopter mission.

2. Additional devices are available now and should be considered as candidates for the scout helicopter mission.

3. Future evaluations of similar optical-viewing devices should use the experimental plan outlined in this report.

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