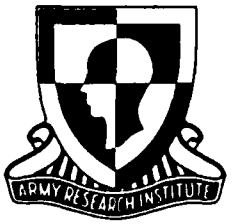
Technical Report 991

The Effect of Restoration of a Field of View on Stinger Team Performance in a Chemical Environment

Joan D. Silver and John M. Lockhart
U.S. Army Research Institute

November 1993



United States Army Research Institute for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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13. ABSTRACT *(Maximum 200 words)*

For this report, the authors investigated the efficacy of restoration of field of view (FOV) in improving Stinger team engagement performance in a chemical environment. Experiment 1 was a laboratory test that established that the FOV of modified M19 binoculars and a modified Stinger sight were significantly greater than those of the unmodified binoculars and Stinger sight when used with a chemical protective mask.

Experiment 2 was a field test to determine the effectiveness of the modifications in improving performance. In overall comparisons among the three conditions, wearing the mask did not significantly impair performance. However, when the effects of learning the test environment are removed from the data, the results are exactly as predicted. Performance in the mask without modifications FOV condition is much worse than in the no mask and mask with modifications FOV conditions. Performance in the no mask and mask with modifications FOV conditions is virtually identical.

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The Effect of Restoration of a Field of View on Stinger Team Performance in a Chemical Environment

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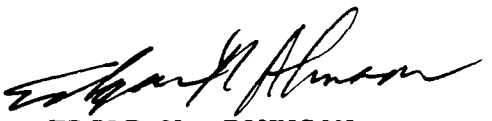
FOREWORD

The Crew Weapons Performance Team of the Fort Bliss Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has investigated the effect of chemical protective clothing on the performance of air defenders as part of an ongoing program of research sponsored by the Physiological and Psychological Effects of the Nuclear, Biological, and Chemical Environment and Sustained Operations on Systems in Combat (P^2NBC^2) program, U.S. Army Chemical School, Fort McClellan, Alabama. The results of these investigations suggest that the reduced field of view (FOV) caused by the chemical protective mask was the primary source of the performance decrement seen when Stinger team wore the Mission Oriented Protective Posture (MOPP) clothing. Devices that substantially restored the reduced FOV were tested to determine their effectiveness in improving Stinger performance.

The results of the research were briefed to the P^2NBC^2 joint working group and technical and scientific advisory group. The findings from this research have implications for all military personnel using binoculars, weapon sights, or any other optical devices in combination with chemical protective masks.



EDGAR M. JOHNSON
Director

THE EFFECT OF RESTORATION OF FIELD OF VIEW ON STINGER TEAM PERFORMANCE IN A CHEMICAL ENVIRONMENT

EXECUTIVE SUMMARY

Requirement:

To investigate the efficacy of restoration of field of view (FOV) in improving the performance of Stinger team chiefs and gunners when wearing the chemical protective mask.

Procedure:

The research was conducted in two phases. Experiment 1 was a laboratory test in which the FOV were quantified for three experimental conditions: (1) no mask, (2) mask, and (3) mask with modified M19 binoculars and Stinger sight. Twelve Stinger personnel participated. Experiment 2 was a field test to determine the effectiveness of the modifications to the binoculars and Stinger sight in improving performance when the chemical protective mask was worn. Twelve Stinger teams (team chief and gunner) participated.

Findings:

The modifications to the binoculars and Stinger sight significantly improved the FOV when the chemical protective mask was worn relative to the condition in which no modifications were made to the binoculars and Stinger sight. The reduced FOV associated with wearing the mask did not significantly impair performance during the field test. However, an apparent effect of "learning the test environment" may have affected the influence of the independent variable. This became evident through examination of the data from the first eight trials given to each team on each test day. The data from these trials, which are believed to be free from the effects of learning the test environment, were exactly as predicted. Performance in the mask FOV condition was very poor relative to the no mask and mask with modifications FOV conditions. Performance in the no mask and mask with modifications FOV conditions was virtually identical.

Utilization of Findings:

These results should serve as the impetus for further research testing the modified binoculars and Stinger sight as a way of improving Stinger engagement performance in a chemical environment.

THE EFFECT OF RESTORATION OF FIELD OF VIEW ON STINGER TEAM PERFORMANCE IN A CHEMICAL ENVIRONMENT

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CONTENTS (Continued)

THE EFFECT OF RESTORATION OF FIELD OF VIEW ON STINGER TEAM PERFORMANCE IN A CHEMICAL ENVIRONMENT

Introduction

Soldiers in combat in a chemical environment are required to wear a flexible system of protection known as Mission Oriented Protective Posture (MOPP). This system provides five levels of protection, MOPP0 through MOPP4. In level 1 or MOPP0, a soldier is attired in his battle dress uniform (BDU), carries a chemical protective mask, and has the other components of the protective clothing readily available to him. A soldier in level 5 or MOPP4 is fully encapsulated in the protective clothing; he wears an overgarment consisting of a jacket and trousers, boots, gloves, and a mask.

Bensel, Teixeira, and Kaplan (1987) have shown that the components of the chemical ensemble (overgarment, gloves, boots, and mask) can act alone or in concert to impede body mobility, psychomotor coordination, and manual dexterity. They conducted an extensive laboratory investigation of the effects of the components of the MOPP gear on ten tasks of body mobility, two visual-motor coordination tasks, and two tests of manual dexterity. In spite of the fact that the overgarment is generally perceived as being cumbersome and bulky, it was found to significantly impede body mob .ity on only two measures of upper leg movement. The M17A1 version of the chemical protective mask used in their research significantly impaired head flexion and head rotation, but did not affect the other measures of body mobility, visual-motor coordination, or manual dexterity. The butyl rubber gloves, worn with cotton liners, significantly impaired performance on the two manual dexterity tests, replicating results previously found by Johnson and Sleeper (1986). The gloves had no effect on any of the other dependent measures. The boots, designed to be worn over standard-issue combat boots, produced no statistically significant differences for any of the comparisons in this research, not even for a task that required participants to walk a rail in heel-to-toe fashion with hands grasped behind the back. Various combinations of the overgarment, mask, and gloves significantly affected head movement, pursuit rotor tracking, and manual dexterity, and the complete MOPP4 attire significantly affected head flexion and rotation and all psychomotor coordination tasks.

The adverse effects of the chemical protective clothing were found also in field tests of Stinger teams engaging subscale aircraft in an engagement simulation facility (Johnson & Silver, 1992; 1993). The performance of both the team chief and the gunner was degraded by the MOPP gear. Ranges and times at which engagement events took place were significantly worse in MOPP4 than in MOPP0.

The observations of behavioral scientists who were present during the Stinger field tests were coupled with the findings of Bensel et al. (1987) and Johnson and Sleeper (1986) to evaluate

the primary cause of the Stinger performance decrement in MOPP4. Based on scientific observation, findings from previous research, and the nature of the Stinger team engagement task, the overgarment, boots, and gloves were ruled out and the chemical protective mask was isolated for investigation as the principal source of the impaired performance.

The contention that the mask is the cause of the degraded performance finds support in the research of Bensel et al. (1987), Harrah (1985), and Kobrick and Sleeper (1986). Central to each study is the premise that the reduced field of view (FOV) caused by the mask impairs functional vision. Bensel et al. found that the reduced FOV caused by the chemical protective mask seriously impairs functional vision. They quantified the limits of the M17A1 mask using 12 volunteer soldiers as participants. The FOV was measured for ten separate areas of the visual field of each eye, with and without the M17A1 mask. Bensel et al. found that each of the ten areas was restricted when the mask was worn relative to a no mask condition, with some areas incurring more serious restriction than others.

Harrah (1985) found that the chemical protective mask both reduced the FOV and impaired the ability of soldiers to scan with military issue binoculars (a task required of Stinger teams). Harrah tested soldiers who wore the M17 chemical protective mask and three prototype versions of the M40 mask, the XM40-1, XM40-2, and XM40-3. Each of the four masks created a standoff distance from the eye to the lens of either 1.5 or 1.6 inches. This standoff reduced the FOV of the M19 binoculars from an average of 6.6 degrees when no mask was worn to an average of 2.9 degrees when the binoculars were used in combination with the masks. The effect of the reduced FOV was to increase the scan time for each of the four mask conditions equally and significantly. Harrah recommended that the relationships between standoff and field of view be verified in field tests of combat tasks.

Additional support for the contention that a reduced FOV impairs performance using functional vision is supplied by Kobrick and Sleeper (1986). They examined the effect of wearing MOPP4 gear on the ability of soldiers to detect signals throughout the visual field during an eight-hour test which included both hot and humid conditions. The signal detection task was chosen because it is representative of many military operational tasks such as sentry surveillance, aerial reconnaissance of ground targets, target detection (a task performed by Stinger teams), and ranging by tank commanders. Kobrick and Sleeper found that signal detection response time increased systematically and significantly for targets which appeared in the peripheral area of the visual field in both MOPP conditions--MOPP4 under comfortable temperature and relative humidity conditions and MOPP4 under hot and humid conditions. Although performance was poorer under the MOPP4 hot and humid conditions, it was not significantly different from performance under MOPP4 comfortable conditions.

An important finding from the Kobrick and Sleeper (1986) research was that the degrading effects of the MOPP gear on functional vision occurred early in the test and remained at a high level for the entire test period. This finding highlights the serious effects of the chemical protective clothing on the functional field of vision, regardless of heat exposure, and the fact that these effects will continue to depress performance as long as the MOPP gear is worn. This finding becomes critical when considering solutions for the problems created by the MOPP gear. Although generally it has been found that training a combat task while in MOPP gear overcomes the performance deficit associated with a particular article of chemical protective clothing or with the entire ensemble (Headley, Brecht-Clark, Feng, and Whittenburg, 1988), it can be inferred from the findings of Kobrick and Sleeper that training in MOPP4 may not mitigate the impaired performance associated with the effects of the chemical protective mask on the visual system. The finding that impairment occurred early and remained constant throughout the 8-hour test period suggests that means other than training may be needed to overcome the detrimental effects of the chemical protective mask on tasks requiring functional vision.

One alternative approach to training is to provide a mechanical device which would increase the FOV reduced by the chemical protective mask. Increasing the FOV could mitigate the performance decrements observed when the protective mask is worn.

The purpose of the present study was to investigate the effect of increasing the FOV on the engagement performance of Stinger teams wearing the protective mask. It was hypothesized that restoration of a substantial portion of the FOV normal to a no mask condition would result in improved engagement performance for Stinger teams. It was additionally hypothesized that the restored FOV would have the added psychological benefit of reducing perceptions of workload and stress. Two experiments were conducted to test these hypotheses.

Experiment 1 was a laboratory test in which the FOV were established for the Stinger sight and for the M19 binoculars under six experimental conditions. Experiment 2 was conducted at the Range Target System (RTS) engagement simulation facility at White Sands Missile Range, New Mexico, where Stinger teams engaged subscale aircraft under three experimental conditions to establish the efficacy of the restored FOV in improving engagement performance.

Experiment 1

Method

Experiment 1 was conducted in the vision research laboratory of the Fort Bliss Field Unit of the Army Research Institute. The purpose of the experiment was to determine the FOV for six conditions: (1) Stinger sight alone, (2) M40 chemical protective mask and Stinger sight, (3) M40 chemical protective mask and

modified Stinger sight, (4) M19 binoculars alone, (5) M40 chemical protective mask and M19 binoculars, and (6) M40 chemical protective mask and modified M19 binoculars.

Participants

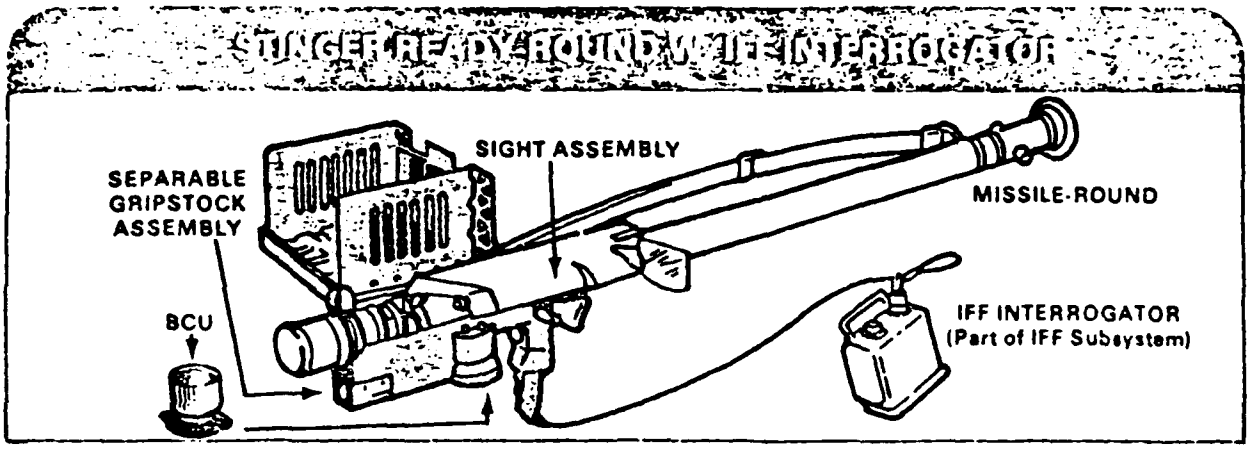
Twelve Stinger soldiers (16S Military Occupational Specialty [MOS]) participated in this research. Ages of the participants ranged from 19 to 39 years (M = 27.25). There was a bimodal distribution of age, 19 to 21 years (N = 6) and 29 to 39 years (N = 6).

Apparatus

The apparatus for FOV measurement consisted of a white, free-standing, 8 feet (horizontal plane) by 6 feet 3 inch (vertical plane) board upon which 6 feet long by 3 3/4 inches wide strips of white paper were centered in the vertical and horizontal plane, forming a cross. A small white light (less than 1/4 inch diameter) was mounted at the center of the cross, providing a fixation point for the participants. The strips of white paper which formed the four arms of the cross were each marked in 1/2 inch increments from the center of the board to the end of each arm (3 feet each in length or 72 half-inch increments). A black pointer could be moved along each of the four arms to and from the center of the apparatus via a system of pulleys mounted on the rear of the apparatus. Four flood lights were directed at the stimulus to provide a constant source of illumination in the otherwise darkened room.

Two M19 standard military issue 7 x 50 binoculars were used, one with modifications and one without. One pair of binoculars was modified by replacing each of the eyepieces with a device used by underwater photographers. This device restores the FOV which was reduced by the combination of the diving mask and the camera's underwater housing. The purpose of the modification was to restore the maximum amount of the original FOV of the binoculars when they are used with the chemical protective mask.

Two Stinger sight assemblies were used, one with modifications and one without. The sight of one assembly was modified by increasing the size of the rear peepsight from 1/8 inch diameter to 5/8 inch (see Figure 1). The sight was modified to restore as much as possible of the original FOV when it was used with the chemical protective mask.



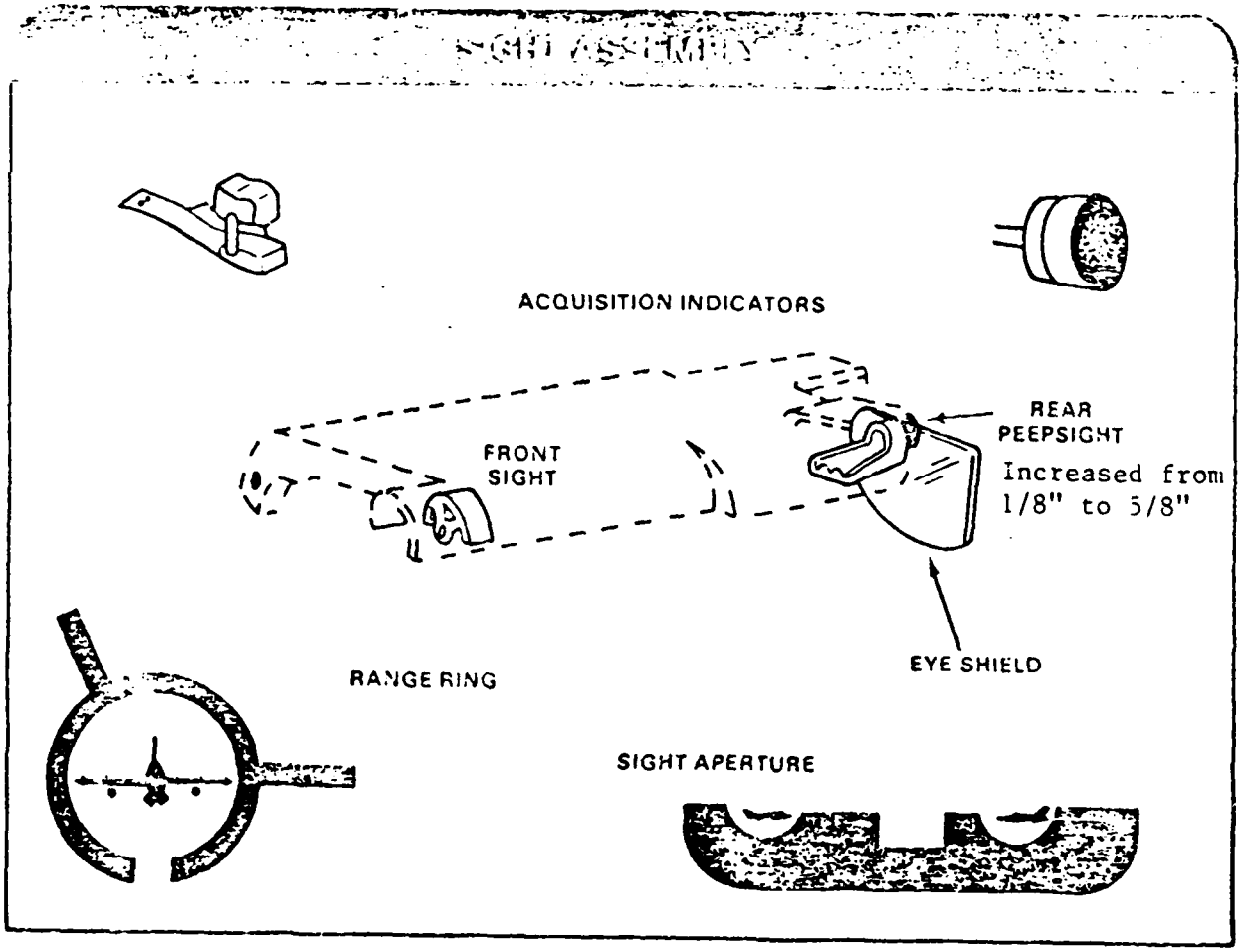


Figure 1. Stinger sight assembly (FM 44-18-1, 1984).

Both pairs of binoculars and both Stinger sight assemblies were individually attached, as required by experimental conditions, via wing-nut and screw, to a tripod mounted on a section of plywood board. The tripod could be adjusted horizontally and vertically.

Procedure

After giving informed consent, each participant was given a period of instruction and demonstration. Participants were assigned to no mask and mask conditions in counterbalanced order. Within these conditions, use of the binoculars (with and without modifications) and Stinger sight (with and without modifications) occurred in randomized order. The order of direction of trials (top, bottom, left, right) was randomized within 6 FOV conditions. The 6 FOV conditions were: (1) no mask and binoculars, (2) no mask and Stinger sight, (3) mask and binoculars, (4) mask and Stinger sight, (5) mask and modified binoculars, and (6) mask and modified Stinger sight.

Twelve trials were conducted in each of the 6 FOV conditions. There were six vertical FOV trials and six horizontal FOV trials (three in each direction--top to center, bottom to center, left to center, and right to center) in each of the six FOV conditions, for a total of 72 trials.

Participants were seated on an adjustable chair which was placed on the plywood platform holding the tripod. Each participant wore a black eyepatch over the left eye during Stinger sight trials only. The Stinger weapon sight is used only with the right eye.

Prior to a sequence of trials in each FOV condition, participants were instructed to center the binoculars and the Stinger sight on the white fixation light in the middle of the stimulus. Participants were cautioned not to shift their gaze in any direction, but to remain fixated on the white light throughout each sequence of trials. They were told that a black pointer would be moved inward toward the fixation light in the center of the stimulus from one of the four directions and that they should say "stop" as soon as they detected the pointer with their peripheral vision. They were then to name the direction from which the pointer appeared (top, bottom, left, right). A data collector recorded the position at which the participant detected the pointer. One set of practice trials was administered before each of the six FOV conditions. A set of practice trials consisted of moving a pointer from the extremity of an arm toward the center of the stimulus in each of the four directions until the participants detected the pointer and said "stop."

Testing occurred over a period of 3 days, with four participants being tested each day. Participants were seated twenty feet from the stimulus for all binocular testing and eleven feet from the stimulus for Stinger sight testing. The

platform with the tripod and chair was moved into position as required by experimental condition. The M40 protective mask was used by all participants.

Results and Discussion

Hypotheses established a priori stated that the FOV measured both when no mask was worn and when the mask was used with the modified binoculars and Stinger sight would be significantly greater than those measured when the mask was used with the unmodified binoculars and unmodified Stinger sight. The results of a series of within-subjects planned comparisons (Keppel, 1973) performed on the FOV means are listed in Table 1. The horizontal and vertical fields of view for the binoculars and the Stinger sight appear in Figures 2 and 3, respectively. Close to 90 percent of the original FOV was restored by the modified binoculars and about 70 percent of the original FOV of the Stinger sight was restored.

The experimental hypotheses were fully confirmed; the FOV for the mask with the unmodified binoculars and mask with unmodified Stinger sight assembly were significantly smaller than those for the other two FOV conditions.

If indeed a reduced FOV is the cause of the decrement seen with the Stinger teams performing the engagement sequence, then restoration of a substantial portion of that FOV should result in improved performance. This hypothesis was tested during Experiment 2.

Table 1

Planned Comparison of Mean Fields of View

Means (degrees)		Results
Vertical Field of View		
	M19 Binoculars	
No Mask vs. Mask		
6.4	1.89	$F(1,11) = 1356$ *
Mask vs. Mask/Modifications		
1.89	5.39	$F(1,11) = 2458$ *
	Stinger Sight	
No Mask vs. Mask		
13.5	6.37	$F(1,11) = 204.48$ *
Mask vs. Mask/Modifications		
6.37	9.25	$F(1,11) = 138.25$ *
Horizontal Field of View		
Means (degrees)		Results
	M19 Binoculars	
No Mask vs. Mask		
6.72	2.20	$F(1,11) = 422.69$ *
Mask vs. Mask/Modifications		
2.20	5.81	$F(1,11) = 340.13$ *
	Stinger Sight	
No Mask vs. Mask		
15.67	6.78	$F(1,11) = 389.48$ *
Mask vs. Mask/Modifications		
6.78	10.76	$F(1,11) = 93.49$ *

* $p<.001$

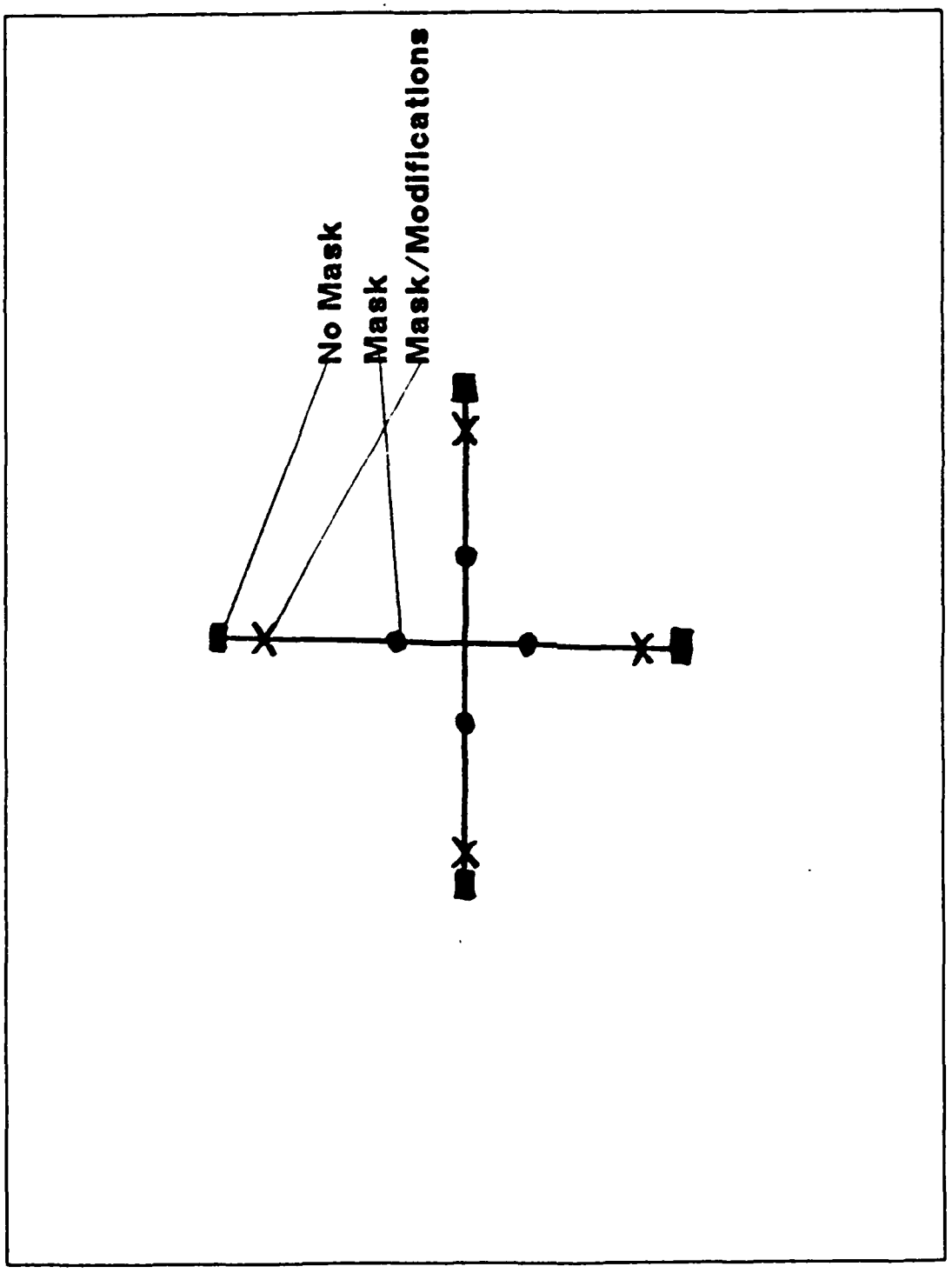


Figure 2. M19 binoculars fields of view.

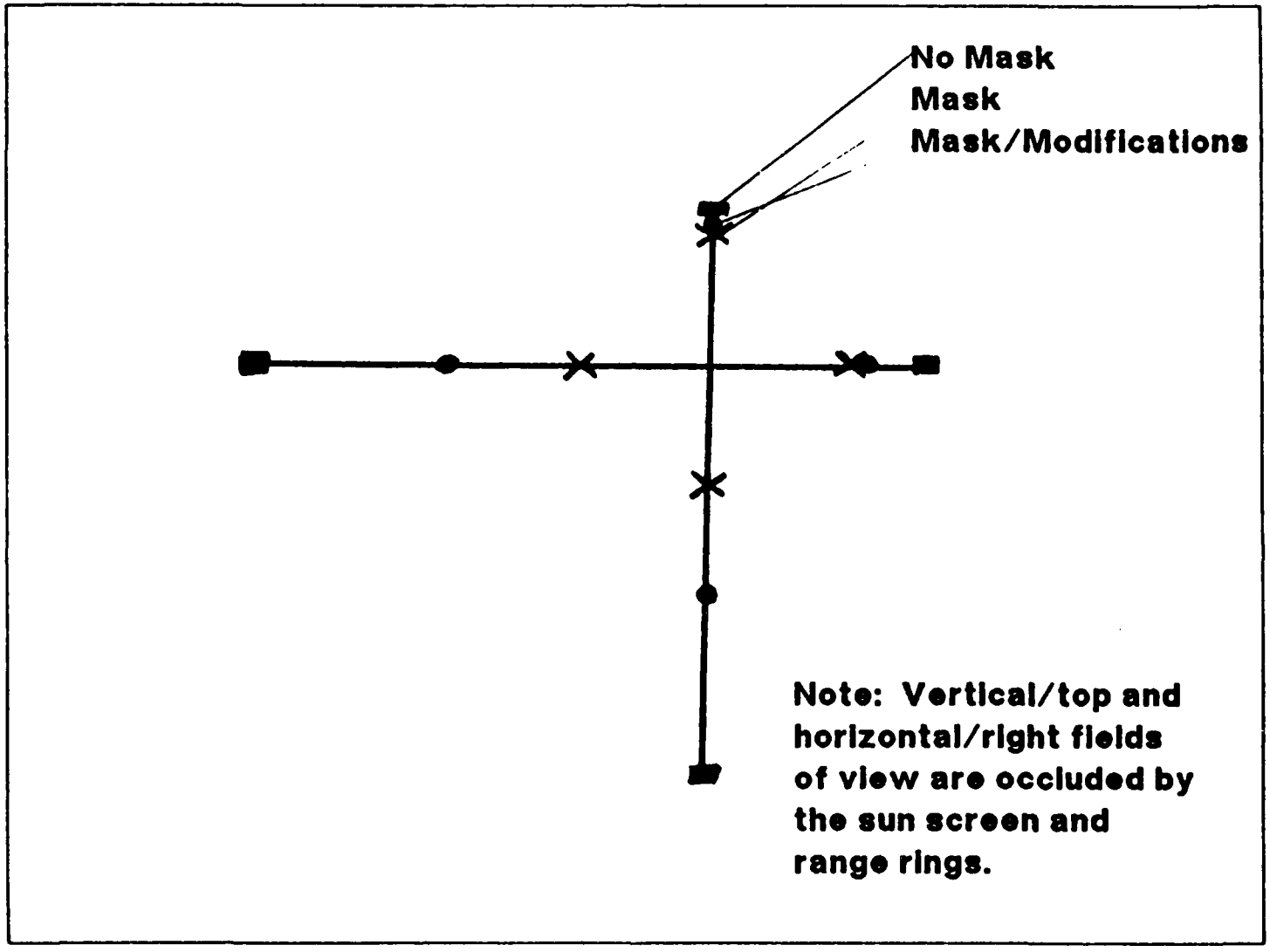


Figure 3. Stinger sight fields of view.

Experiment 2

Method

The purpose of Experiment 2 was to determine the effect of restoration of FOV on Stinger engagement performance and also to determine whether the restored FOV produced the added psychological benefit of reducing subjective perceptions of workload and stress.

Participants

Participants in this research consisted of 12 Stinger teams (team chief and gunner). Ages of the participants ranged from 18 to 29 years (M = 21.04).

Apparatus

Testing took place at the Range Target System (RTS) engagement simulation facility located at White Sands Missile Range, New Mexico. Participants employed the Stinger Tracking Head Trainer (THT) in simulated engagement of subscale fixed-wing and rotary-wing aircraft in the RTS facility. The THT is a Stinger weapon system training device which develops and maintains gunner proficiency in tracking aircraft and firing the Stinger weapon. The missile seeker on the THT works the same as that on the weapon and the audiovisual indications when acquiring and tracking a target are also the same as the weapon (FM 44-18-1, 1984).

All targets were one-fifth scale, three-dimensional, molded fiberglass replicas of US or Soviet aircraft. The fixed-wing aircraft were flown remotely according to prescribed flight paths and maneuvers. The rotary-wing aircraft appeared from designated positions via pneumatic stand-lift mechanisms.

Each of four Stinger THTs was cabled to a Data Acquisition Station (DAS). Signal taps were installed on key weapon pins. Gunner actions were collected automatically by the DAS and time coded with a resolution of 250 msec. Team chief detection and identification actions were recorded by four data collectors who entered keystrokes on DAS computer keyboards located at each weapon position.

Procedure

After giving informed consent, each participant received 8 engagement trials in each of the FOV conditions: (1) no mask with binoculars or Stinger sight (no mask FOV condition), (2) mask with binoculars or Stinger sight (mask FOV condition), and (3) mask with modified binoculars or modified Stinger sight (mask/modifications FOV condition). FOV conditions were counterbalanced over DASs.

Engagement scenarios in each of the 3 FOV conditions included friendly and hostile aircraft. Engagement scenarios consisted of single rotary-wing aircraft, single fixed-wing aircraft, a mix of one fixed-wing and one rotary-wing aircraft, or two rotary-wing aircraft.

The start of an engagement trial was signalled by the verbal alert "Red Tight" and the end of a trial was signalled by the verbal alert "Condition Yellow." The signals were given by the data collectors assigned to the teams.

Participants filled out a Self-Evaluation Questionnaire before and after each of the 3 FOV conditions. The Self-Evaluation Questionnaire assesses state anxiety which is a reaction or process taking place at a given time and level of intensity (Spielberger, 1983). The scale consists of 20 statements intended to evaluate how respondents feel at a particular moment in time. The ratings given by participants were used to quantify stress levels experienced before and after each of the three sequences of engagement trials.

After each engagement trial in each FOV condition, participants rated workload for that trial using the National Aeronautics and Space Administration (NASA) Task Load Index (TLX) rating scale (NASA-Ames, 1986). The TLX is a multidimensional rating procedure that derives an overall workload score from six subscales; mental demand, physical demand, temporal demand, effort, performance, and frustration.

Testing occurred over a period of three days with four Stinger teams being tested on each day. At the end of a test day, each data collector provided his team with feedback on their performance over the 24 engagement trials. A structured interview was also conducted in which soldiers were queried about their subjective impressions of the modified binoculars, modified Stinger sight, the chemical protective mask, and prior experience in MOPP gear.

Results and Discussion

Hypotheses established a priori stated that Stinger teams would perform better both in the no mask FOV condition and in the mask/modifications FOV condition than in the mask FOV condition. Data were collected on task performance measures (TPM) and summary performance measures (SPM) for both fixed-wing and rotary-wing aircraft. TPMs are expressed as ranges for the fixed-wing aircraft and as elapsed time for the rotary-wing aircraft. SPMs are collected by summing over scenarios and are expressed as percentages. A series of within-subjects planned comparisons (Keppel, 1973) were carried out on the appropriate means. The TPMs are presented first.

Task Performance Measures

The rotary-wing engagement event means and the results of the within-subjects planned comparisons (Keppel, 1973) performed on these means are listed in Tables 2 and 3. The means for the 3 FOV conditions are represented graphically in Figure 4. AVL-DET is the time from availability of the target to the detection response. DET-ID is the elapsed time from the detection response to identification of the aircraft. DET-IFF is the elapsed time from target detection to identification friend or foe button press. DET-ACQ is the time from detection to weapon acquisition signal and ACQ-LO is the elapsed time from weapon acquire signal to the press of the uncage bar which locks the missile onto the target. LO-FIR is the time from the press of the uncage bar to fire trigger pull. ID-FIR is the time from the identification response to fire trigger pull. DET-FIR is the elapsed time from the detection response to the fire trigger pull. AVL-FIR is the time from availability of target until the fire trigger pull.

Table 2

Rotary-Wing Engagement Event Within-Subjects Planned Comparisons for the No Mask vs. Mask FOV Conditions

Engagement Event	Means (sec) No Mask	Mask	Results
AVL-DET	9.06	10.50	$F(1,10) = 1.27$
DET-ID	9.64	9.76	$F(1,10) = .02$
DET-IFF	3.22	4.21	$F(1,9) = .13$
DET-ACQ	10.34	10.59	$F(1,9) = .02$
ACQ-LO	5.28	5.45	$F(1,9) = .03$
LO-FIR	2.18	2.50	$F(1,9) = 1.89$
ID-FIR	7.43	7.92	$F(1,9) = .19$
DET-FIR	15.84	16.20	$F(1,9) = .04$
AVL-FIR	24.20	25.20	$F(1,9) = .18$

All comparisons are non-significant

Table 3

Rotary-Wing Engagement Event Within-Subjects Planned Comparisons for the Mask vs. Mask/Modifications FOV Conditions

Engagement Event	Means (sec) Mask	Mask/Mods	Results
AVL-DET	10.50	9.41	$F(1,10) = 1.96$
DET-ID	9.76	9.28	$F(1,10) = .17$
DET-IFF	4.21	2.57	$F(1,9) = 1.61$
DET-ACQ	10.59	9.31	$F(1,9) = .56$
ACQ-LO	5.45	3.99	$F(1,9) = .20$
LO-FIR	2.50	1.83	$F(1,9) = 14$ *
ID-FIR	7.92	6.65	$F(1,9) = 1.13$
DET-FIR	16.20	13.86	$F(1,9) = 2.64$
AVL-FIR	25.20	22.35	$F(1,9) = 2.21$

* $p<.05$

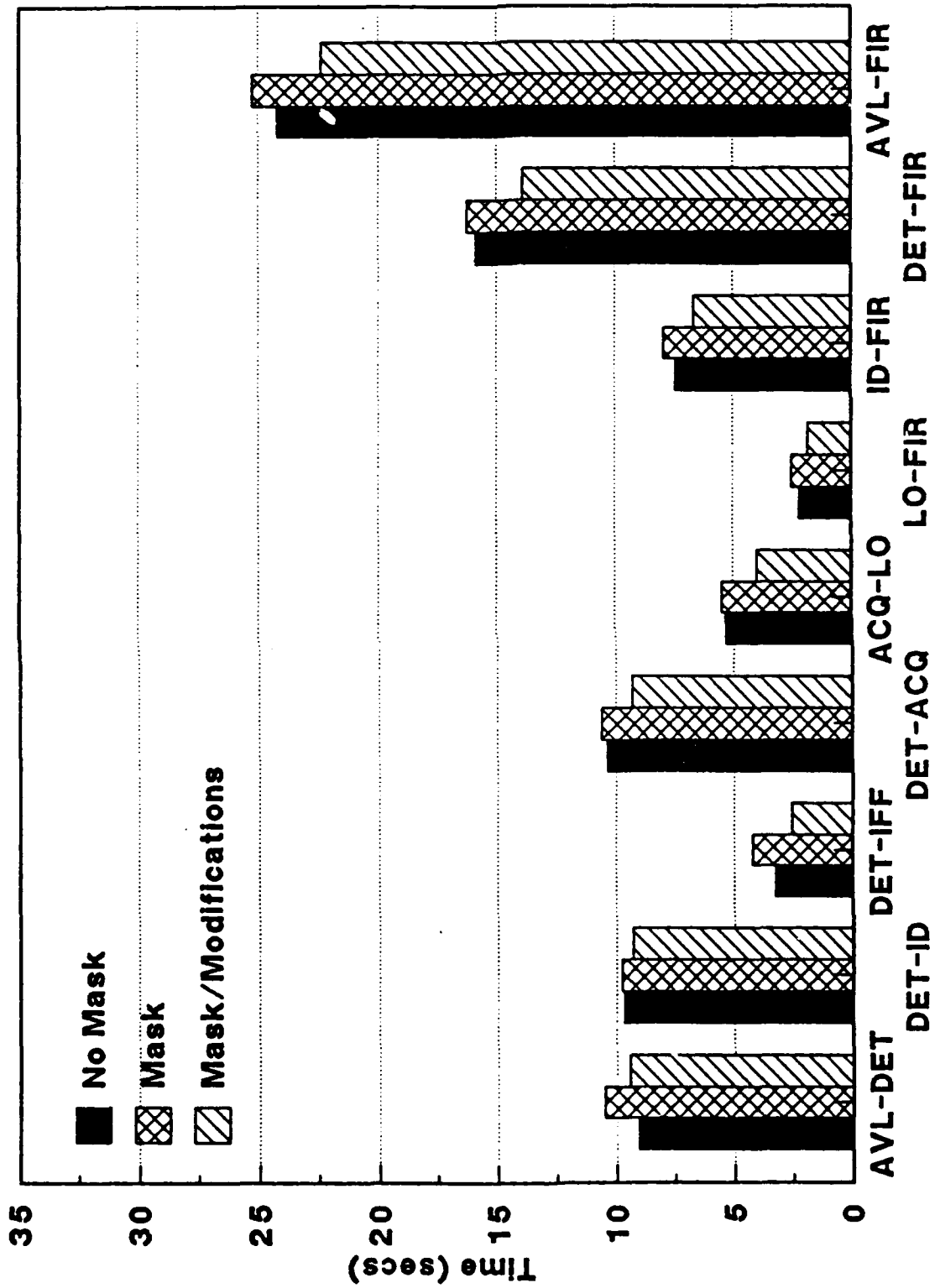


Figure 4. Rotary-wing engagement events by FOV condition.

Tables 4 and 5 contain the fixed-wing engagement event means and results of the within-subjects planned comparisons performed on those means for the 3 FOV conditions. The means for each FOV condition appear in graphic form in Figure 5. DET is the range of the aircraft at the detection response. ID is the aircraft range when a "friendly" or "hostile" identification is made. IFF is the range of the aircraft at identification friend or foe button push. ACQUIRE is the aircraft range at weapon acquisition signal. LOCK-ON is the range of the aircraft at the press of the uncage bar which locks the missile onto the target. FIRE is the aircraft range at fire trigger pull.

The hypothesis that performance in both the no mask and in the mask/modifications FOV conditions would be superior to that in the mask FOV condition was not supported statistically; only one of the thirty comparisons, LO-FIR, was significantly different. However, 29 of the 30 comparisons were in the predicted direction--i.e., performance was better both in the no mask and mask/modifications FOV conditions than in the mask FOV condition.

The absence of significant differences between the no mask and mask FOV conditions suggests that wearing a chemical protective mask does not impair Stinger engagement performance. Additionally, the lack of significant differences between the mask and mask/modifications FOV conditions seemingly indicates that restoration of FOV to the binoculars and Stinger sight when used with the chemical protective mask has no beneficial effect on Stinger engagement performance. However, the presence of a body of research (Johnson & Silver, 1992; 1993) which showed clearly that MOPP gear significantly impaired the engagement performance of three different groups of Stinger teams tested on three separate occasions warrants caution before accepting such conclusions. In each Stinger test, the performance of both the team chief and the gunner was significantly degraded by the MOPP gear.

Furthermore, before accepting these conclusions, one must take into consideration that 29 of 30 comparisons of Stinger engagement performance were in the predicted direction. The regularity and orderliness of the data strongly suggested that wearing the mask impaired performance and that the modifications to the binoculars and to the Stinger sight were improving performance.

Given the evidence from prior research documenting the degrading effects of the MOPP gear on Stinger performance and the trends present in our data, it became incumbent on us to search for possible alternative explanations for our results. The ensuing search uncovered three problems--small sample size, substantial variability, and the possibility of learning effects inherent in the test environment--which, acting together, held the potential for reducing the effect of our independent variable.

Table 4

Fixed-Wing Engagement Event Within-Subjects Planned Comparisons for the No Mask vs. Mask FOV Conditions

Engagement Event	Means (km) No Mask	Mask	Results
DET	8.015	7.171	$F(1,9) = .07$
IFF	6.797	6.120	$F(1,9) = 2.15$
ACQUIRE	3.304	2.715	$F(1,9) = .30$
ID	3.791	3.111	$F(1,9) = .17$
LOCK-ON	.627	.398	$F(1,9) = .45$
FIRE	.554	-.519	$F(1,9) = .09$

All comparisons are non-significant

Table 5

Fixed-Wing Engagement Event Within-Subjects Planned Comparisons for the Mask vs. Mask/Modifications FOV Conditions

Engagement Event	Means (km) Mask	Mask/Mods	Results
DET	7.171	7.485	$F(1,9) = .17$
IFF	6.120	6.261	$F(1,9) = .04$
ACQUIRE	2.715	3.096	$F(1,9) = .12$
ID	3.111	2.920	$F(1,9) = .78$
LOCK-ON	.398	.539	$F(1,9) = .35$
FIRE	-.519	.237	$F(1,9) = .05$

All comparisons are non-significant

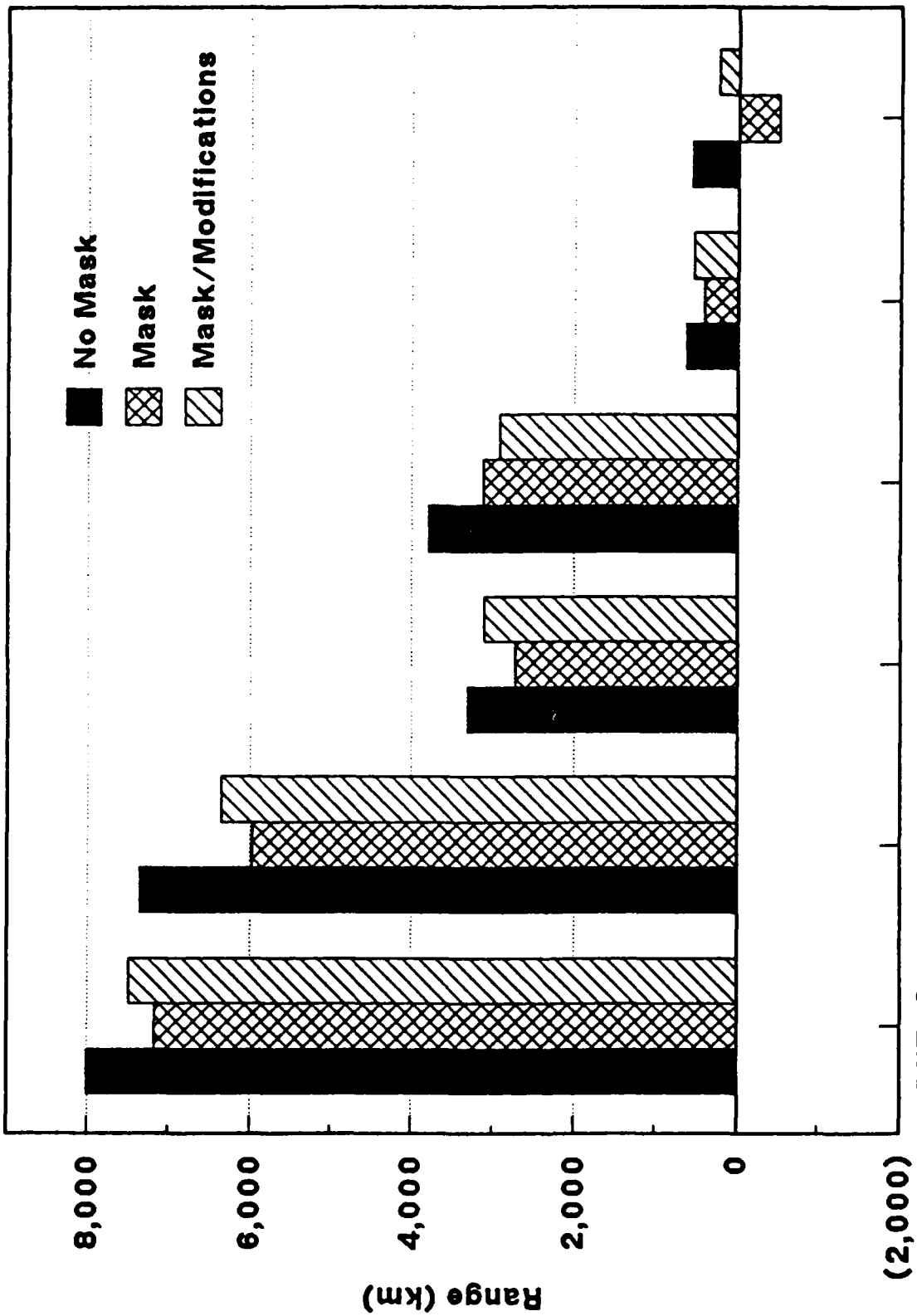


Figure 5. Fixed-wing engagement events by FOV condition.

The effects of sample size and variability must stand, but the effects of learning the test environment were isolated by examining the data at a point at which they had not had an opportunity to confound performance--during the first sequence of eight trials given each test day. We define "learning the test environment" as assembling specific pieces of information about the RTS engagement facility which can subsequently reduce the effects of the independent variable over the course of the test day; in this research, of reducing the advantages of not wearing a mask and of having modified binoculars or Stinger sight.

For example, during any given set of engagement trials the helicopters appeared at fixed locations. Participants were able to learn these locations after exposure to the aircraft. Once located, a helicopter in a fixed position did not require tracking, making it an easier target than a fast-moving, maneuvering, fixed-wing aircraft. A fixed-wing target, on the other hand, required continual tracking throughout the trial, making it a much more difficult engagement. Over the course of each test day, it was possible for 21 pop-up helicopters and 9 fixed-wing aircraft to appear. Thus Stinger teams were exposed to rotary-wing aircraft which appeared on multiple occasions in a static environment versus fixed-wing aircraft which appeared less frequently in a dynamic environment.

Although we believe that acquisition of information about the test environment over three sequences of engagement trials reduced the beneficial effects of not wearing a mask and of having modified binoculars or Stinger sight, the data yielded no evidence that this information was also facilitating improved performance (i.e., faster aircraft detection). In fact, it is unlikely that acquisition of information about the test environment in and of itself would be useful in improving performance because feedback was not given during the course of the day regarding the correctness of aircraft identification or the ranges and times at which engagement events occurred. Because of the powerful effect of that variable on performance, feedback was not given until the end of the test day, after completion of 24 engagement trials.

If indeed acquisition of information about the test environment was reducing the effects of the no mask and the mask/modifications FOV conditions, then evidence to support this hypothesis should be found in the data from the first sequence of trials administered to each team on each test day. If this hypothesis can be supported, then the data from these eight trials should reveal that the differences between the no mask and mask FOV conditions, and the mask and mask/modifications FOV conditions are substantially larger during the sequence one trials where the data are not confounded than the differences obtained when the data were combined over all three sequences of engagement trials. That is exactly what was found.

The no mask engagement means were compared to the mask means for fixed-wing and rotary-wing events. The mask means were also compared to the mask/modifications means. The rotary-wing engagement events are presented first. Because our sample size was now reduced to 4, statistical analyses were not performed on the data; only descriptive statistics are provided.

Rotary-wing engagement events: Sequence one. The sequence one rotary-wing engagement event means for each of the FOV conditions are listed in Table 6. These means are graphically represented in Figure 6. Comparing Figures 4 and 6, it can be seen in the former that the rotary-wing engagement means from the 3 FOV conditions are very similar to each other. As previously noted, we have hypothesized that this is so, at least in part, because of acquiring information about the test environment. On the other hand, the sequence one data displayed in Figure 6, reveal that the mask FOV condition means are generally considerably larger than those from the no mask and mask/modifications FOV conditions. Performance in the no mask and mask/modifications FOV conditions is virtually identical--results which were originally predicted. Restoring the FOV should produce performance similar to that when no mask is worn.

The rotary-wing sequence one data are offered as evidence in support of the hypothesis that acquiring information about the test environment repressed the effect of the independent variable. We acknowledge, of course, that this conclusion is tenuous until supported by further research.

Table 6

Sequence One Rotary-Wing Engagement Events for the Three FOV Conditions

Engagement Event	Means (sec) No Mask	Mask	Mask/Modifications
AVL-DET	10.83	12.11	10.35
DET-ID	8.68	10.72	9.91
DET-IFF	3.95	8.21	2.50
DET-ACQ	8.44	16.00	7.94
ACQ-LO	3.43	4.17	3.40
LO-FIR	2.57	1.92	1.87
ID-FIR	7.46	10.17	6.60
DET-FIR	14.57	20.67	14.00
AVL-FIR	23.14	33.17	24.20

Figure 6. Sequence one rotary-wing engagement events by FOV condition.

Fixed-wing engagement events: Sequence one. The sequence one fixed-wing engagement event means are listed in Table 7; they appear in graphic form in Figure 7. Again, it is helpful to compare the data combined over three sequences of trials (Figure 5) to those from sequence one (Figure 7), in which the effects of learning the test environment are believed not to be present.

It is apparent that the results from the fixed-wing events do not present as strong a case for the consequences of learning the test environment as do those from the rotary-wing events. The no mask FOV condition means are better than the mask FOV condition means for five of six engagement events, but, the mask/modifications FOV condition means are superior to the mask FOV condition only for half of the events. Interestingly, however, the means for the critical team chief event--identification--are as predicted; the no mask and mask/modifications FOV conditions are considerably better than the mask FOV condition. The beneficial effects of modified binoculars are apparent for this engagement event.

The modification to the Stinger sight did not produce a clear-cut benefit for the gunner. He actually performed poorer on three of four engagement events with the modified sight, unlike his rotary-wing performance. Nonetheless, for the critical gunner event--fire--the modified sight evidently aided performance.

Table 7

Sequence One Fixed-Wing Engagement Events for the Three FOV Conditions

Engagement Event	Means (km) No Mask	Mask	Mask/Modifications
DET	7.951	6.621	7.118
IFF	6.697	5.936	5.040
ACQUIRE	4.723	3.376	2.581
ID	3.705	1.374	3.345
LOCK-ON	1.710	1.787	1.309
FIRE	1.292	.262	.972

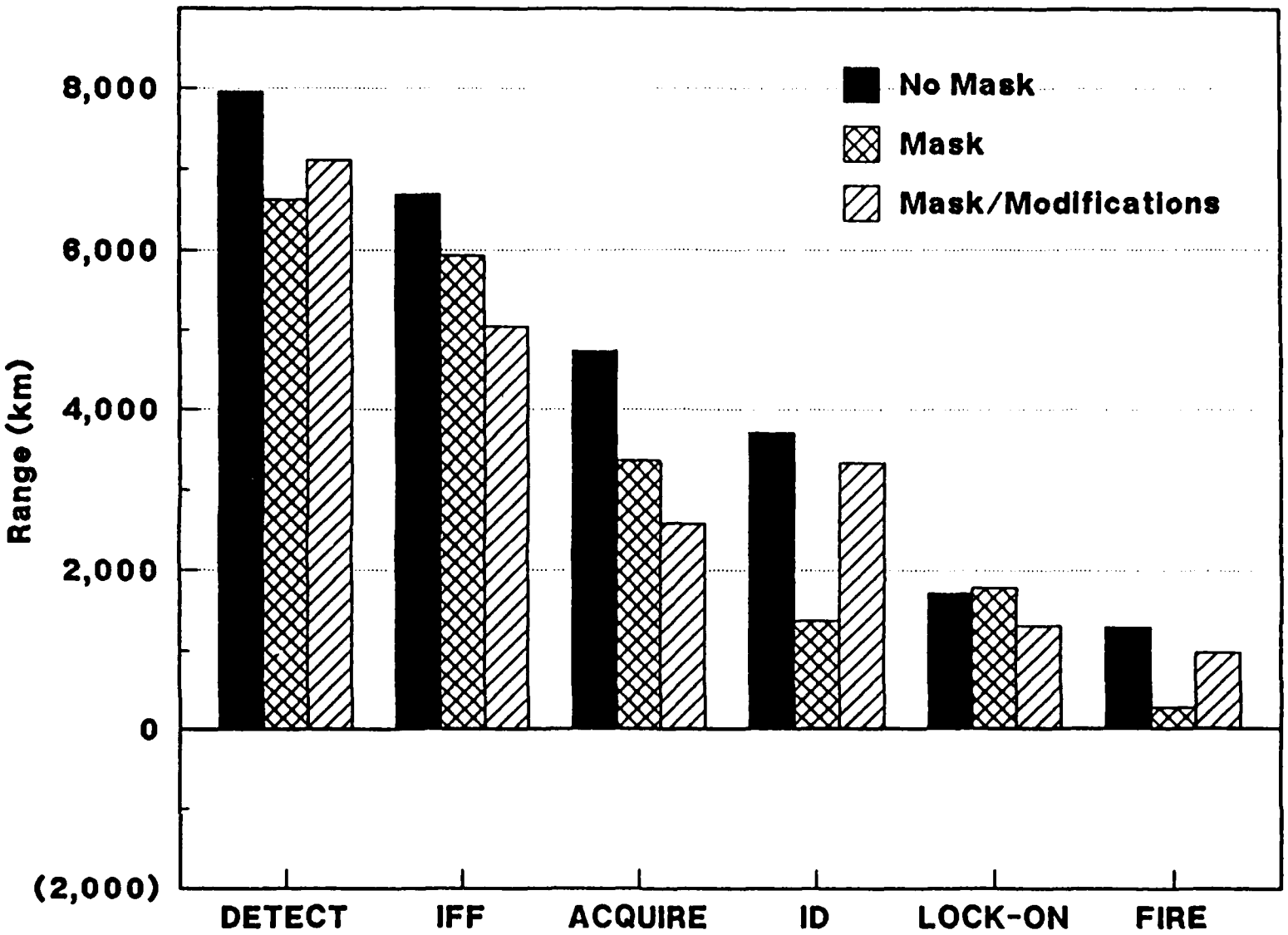


Figure 7. Sequence one fixed-wing engagement events by FOV condition.

Summary Performance Measures

Each summary performance measure is collected by summing across the appropriate engagement scenarios and is expressed as a percentage. The percent aircraft identified correctly is the number of aircraft for which a correct identification response is given divided by the total number of aircraft detected. The percent friendly aircraft identified correctly is the number of friendly aircraft for which a correct identification response is given divided by the total number of friendly aircraft detected. The percent hostile aircraft identified correctly is the number of hostile aircraft for which a correct identification response is given divided by the total number of hostile aircraft detected.

Attrition is defined as the number of hostile aircraft credited as "killed" divided by the total number of hostile aircraft presented. Fratricide is the number of friendly aircraft credited as "killed" divided by the total number of friendly aircraft presented. The number of hostile aircraft "killed" prior to ordnance release is divided by the total number of hostile aircraft presented to calculate that percentage. Ordnance release is defined as 2 km from the weapon for fixed-wing aircraft and 20 sec after target availability for rotary-wing aircraft. The probability of kill given fire is the number of aircraft credited as "killed" (hostile plus friendly) divided by the total number of fire events (fire trigger pulls).

The means for the rotary-wing summary performance measures for no mask and mask comparisons and for the mask and mask/modifications comparisons are displayed in Tables 8 and 9, respectively. These tables also contain the results of the planned comparisons performed on the means. The summary performance measure means for the three FOV conditions appear in graphic form in Figure 8. Tables 10 and 11 contain the fixed-wing summary performance measure means and results. Those means are displayed graphically in Figure 9.

Table 8

Within-Subjects Planned Comparisons of the Summary Performance Measures for Rotary-Wing Aircraft for the No Mask vs. Mask FOV Conditions

Event	Means (percent) No Mask	Mask	Results
ID	78.33	74.18	F(1,32) = .31
Friendly ID	75.00	65.00	F(1,31) = .5
Hostile ID	80.00	80.00	F(1,32) = 0
Attrition	79.58	70.00	F(1,32) = 1.22
Fratricide	20.83	40.00	F(1,31) = 1.9
Ord. Release	0	0	
Prob. Kill	97.92	100.00	F(1,31) = .61

All comparisons are non-significant

Table 9

Within-Subjects Planned Comparisons of the Summary Performance Measures for Rotary-Wing Aircraft for the Mask vs. Mask/Modifications FOV Conditions

Event	Means (percent) Mask	Mask/Mods	Results
ID	74.18	73.58	F(1,32) = .01
Friendly ID	65.00	70.83	F(1,31) = .17
Hostile ID	80.00	71.25	F(1,32) = 1.01
Attrition	70.00	71.25	F(1,32) = .02
Fratricide	40.00	25.00	F(1,31) = 1.16
Ord. Release	0	0	
Prob. Kill	100.00	96.67	F(1,31) = 1.56

All comparisons are non-significant

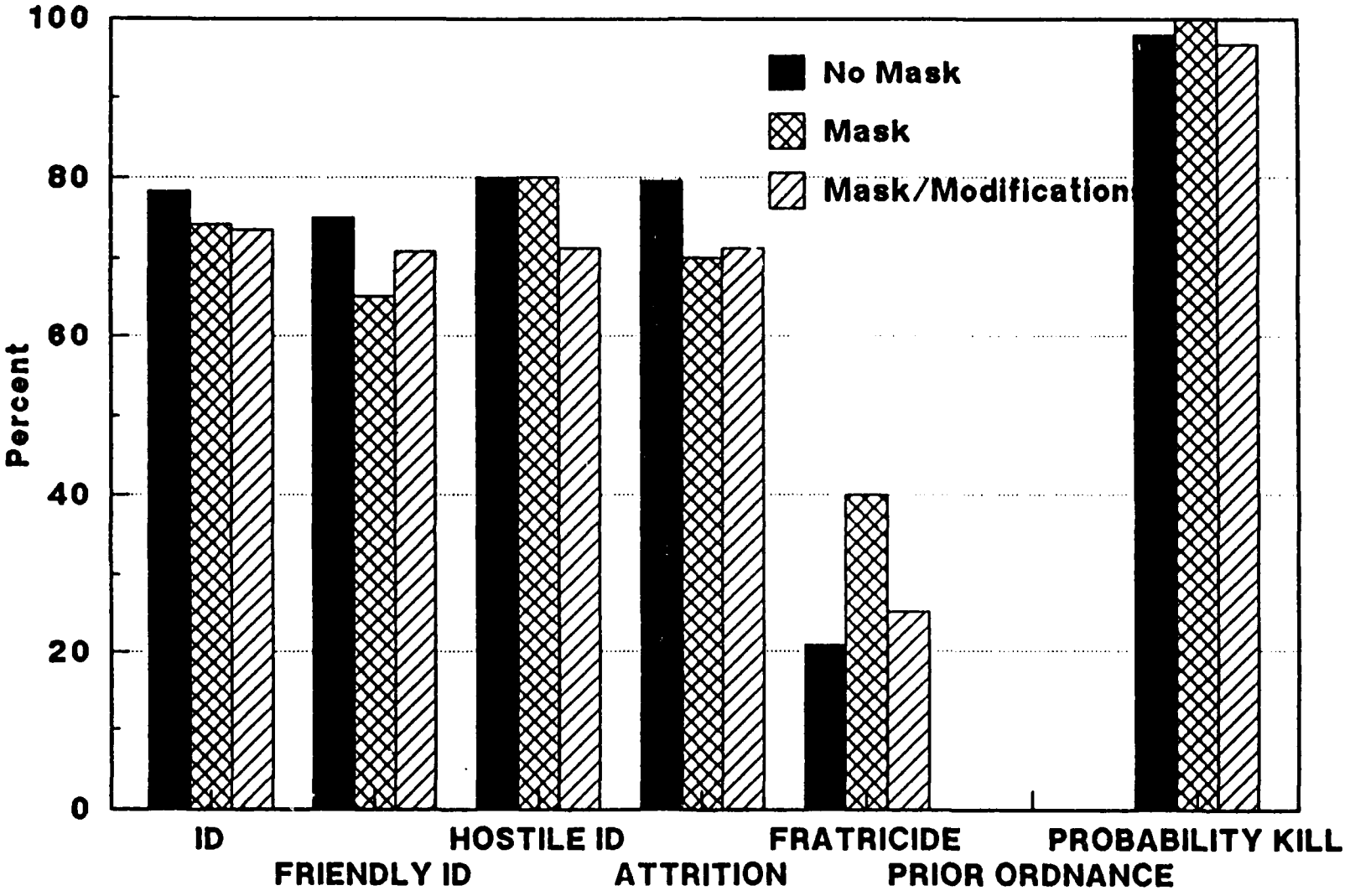


Figure 8. Rotary-wing summary performance measures by FOV condition.

Table 10

Within-Subjects Planned Comparisons of the Summary Performance Measures for Fixed-Wing Aircraft for the No Mask vs. Mask FOV Conditions

Event	Means (percent) No Mask	Mask	Results
ID	90.33	81.80	$F(1,31) = 1.13$
Friendly ID	91.67	70.00	$F(1,31) = 1.44$
Hostile ID	91.67	90.00	$F(1,31) = .05$
Attrition	54.17	25.00	$F(1,31) = 2.37$
Fratricide	0	20.00	$F(1,31) = 1.81$
Ord. Release	20.83	0	$F(1,31) = 3.86$ *
Prob. Kill	66.67	40.00	$F(1,31) = 1.7$

* $p<.10$

Table 11

Within-Subjects Planned Comparisons of the Summary Performance Measures for Fixed-Wing Aircraft for the Mask vs. Mask/Modifications FOV Conditions

Event	Means (percent) Mask	Mask/Mods	Results
ID	81.80	84.83	$F(1,31) = .14$
Friendly ID	70.00	66.67	$F(1,31) = .03$
Hostile ID	90.00	95.83	$F(1,31) = .57$
Attrition	25.00	41.67	$F(1,31) = .77$
Fratricide	20.00	25.00	$F(1,31) = .11$
Ord. Release	0	20.83	$F(1,31) = 3.86$ *
Prob. Kill	40.00	54.17	$F(1,31) = .48$

* $p<.10$

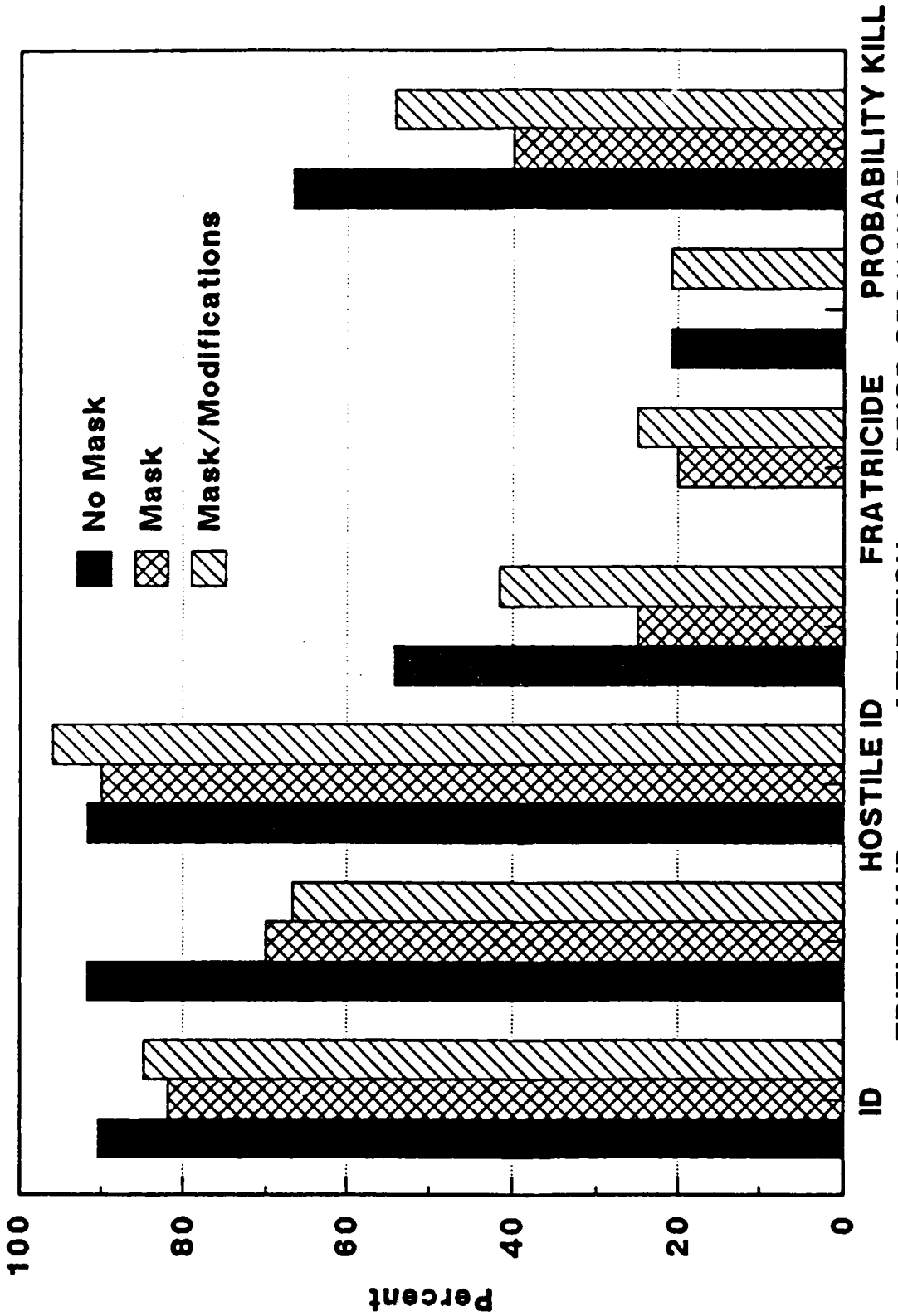


Figure 9. Fixed-wing summary performance measures by FOV condition.

There were no significant differences for any of the rotary-wing summary performance measure planned comparisons. Only two of the fixed-wing comparisons were significantly different; the no mask vs. mask and the mask vs. mask/modifications comparisons for "percent hostile aircraft killed prior to ordnance release." Significantly more aircraft were killed prior to ordnance release in the no mask and mask/modification FOV conditions. The general absence of significant differences is consonant with findings from previous Stinger research (Johnson & Silver, 1991a; 1991b) where it has been found that the MOPP gear usually has little effect on these measures.

The summary performance measures were not examined further because there was no orderly or consistent pattern which suggested the presence of effects of learning the test environment.

Structured Interview - Summary of Comments

At the end of the test day, each data collector conducted a structured interview with his team. Subjective impressions about the modified binoculars and sights, opinions about the chemical protective mask, and information about prior experience in MOPP gear were collected from each soldier.

The participants in this research were generally quite enthusiastic about the modifications to the binoculars and sights. One hundred percent of the gunners who responded (11/11) believed that their performance improved when they used the modified Stinger sight. Seventy-three percent of the team chiefs who responded (8/11) held the same opinion for the modified binoculars. Seventy-three percent (8/11) of the team chiefs and ninety-one percent (10/11) of the gunners attributed the perceived improved performance to the modified devices alone, while 1 gunner (9 percent) believed that the modified sight plus the opportunity to warm up over trials accounted for his perceived improved performance.

Workload Results

NASA TLX rating scales were administered after each engagement trial in each of the 3 FOV conditions. It was predicted that workload ratings would be lower in the no mask and mask/modifications FOV conditions than in the mask FOV condition.

Within-subjects planned comparisons were performed on the data. The workload ratings given in the mask FOV condition (M = 38.06, N = 22) were significantly higher ($F[1,21] = 9.86$, $p<.01$) than those given in the no mask FOV condition (M = 29.81, N = 22). The workload ratings given in the mask/modifications FOV condition (M = 39.68, N = 24), however, did not differ significantly ($F[1,23] = .48$, $p>.05$) from those in the mask condition (M = 37.83, N = 24). Our hypotheses, therefore, were only partially supported. Participants rated workload higher in both mask FOV conditions relative to the no mask FOV condition.

The data suggest that increasing the field of view does not provide psychological relief in the form of reducing perceptions of workload while wearing the mask.

Stress Results

Participants rated stress levels using the Self-Evaluation Questionnaire before and after each sequence of engagement trials. It was expected that stress ratings would be higher in the mask FOV condition than in the no mask and mask/modifications FOV conditions, both pretest and posttest. The means and results of the pretest and posttest analyses for the no mask and mask FOV conditions are listed in Table 12. Table 13 contains the same information for the mask and mask/modifications analyses. The data were analyzed using the Wilcoxon test for within-subjects comparisons (Bruning & Kintz, 1977).

Our hypotheses were not supported by statistical analysis. Although the means for the no mask and mask comparisons are as predicted (see Table 12), they are not significantly different. These results are unlike those from prior research with Stinger teams (Johnson & Silver, 1992; 1993) in which every MOPP0 and MOPP4 comparison was significantly different. In each of previous studies, however, the teams were wearing the entire protective garb, not just the mask as in the present study.

The means for the mask and mask/modifications comparisons (Table 13) were not in the predicted direction and do not approach significance. Like the workload means, it appears that restoration of FOV does not result in lowered perceptions of stress.

Table 12

Wilcoxon Related Groups Analyses of the No Mask vs. Mask Stress Ratings

	No Mask	Mask	Results
	Pretest		
Mean	30.10	32.38	$z = -1.68$
SD	6.80	8.77	
N	20	20	
	Posttest		
Mean	30.65	34.23	$z = -1.87$
SD	8.25	9.57	
N	20	20	

All comparisons are non-significant

Table 13

Wilcoxon Related Groups Analyses of the Mask vs. Mask/Modifications Stress Ratings

	Mask	Mask/Mods	Results
	Pretest		
Mean	32.38	34.00	$z = -.79$
SD	8.74	9.76	
N	24	24	
	Posttest		
Mean	34.23	36.05	$z = -.83$
SD	9.57	8.99	
N	20	20	

All comparisons are non-significant

General Discussion

The FOV of the M19 binoculars and of the Stinger sight when used in combination with the chemical protective mask were significantly improved through modification of both devices. Although the findings of this report appear to support the contention that restoration of FOV improves Stinger engagement performance, the lack of significant results tempers such conclusion. These results, however, should serve as the impetus for further research using the modified binoculars and Stinger sight. To avoid effects of learning the test environment, future research might include pretraining the Stinger teams to standards of performance, increasing the number of scenarios, and use of a between-subjects design.

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