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Research Report 1638

Stinger Team Performance During Engagement Operations in a Chemical Environment: The Effect of Experience

David M. Johnson and Joan Dietrich Silver
U.S. Army Research Institute

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This research compared the engagement performance of two groups of soldiers wearing the standard battle dress uniform (MOPP0) and the full chemical protective ensemble (MOPP4). The two groups of air defense soldiers varied widely in training and experience. Twelve Stinger teams were recruited during their last week of advanced individual training to become the low experience group. Another twelve Stinger teams were recruited from veterans newly returned from Operations Desert Shield and Desert Storm. All teams were tested in the Range Target System (RTS). Measurements were recorded for engagement performance, stress, and workload. Engagement performance was poorer during conditions of MOPP4 for both the lower and high experience groups. Engagement performance was better for the high experience group than for the low experience group regardless of MOPP conditions. Stress and workload ratings were higher when Stinger teams wore MOPP4 than MOPP0.

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Stinger Team Performance During Engagement Operations in a Chemical Environment: The Effect of Experience

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FOREWORD

The research discussed in this report was performed by the Soldier-System Effectiveness Team of the Fort Bliss Field Unit of the U.S. Army Research Institute for the Behavioral and Social sciences (ARI). The mission of this team is to perform research and development in human performance issues relevant to improving Army air defense effectiveness. Field tests have shown that the engagement performance of Stinger teams is impaired by wearing MOPP4 chemical protective clothing for long periods of time during sustained operations. Is this impairment caused (a) by the wearing of the MOPP4 clothing itself, (b) by the requirement to operate in this chemical protective clothing for long durations in sustained operations, or (c) by some interaction between the clothing and the duration it is worn? The objective of this research was to quantify the magnitude of the performance decrement caused specifically by wearing the MOPP4 clothing itself. The effect on performance of extended operations in MOPP4 was not investigated. A second objective of this research was to determine if extensive prior experience with and training in MOPP4 clothing improved engagement performance.

This research is part of a larger team project entitled "Forward Area Air Defense (FAAD) Performance During Engagement Operations in a Chemical Environment," which is funded by the Physiological and Psychological Effects of the Nuclear, Biological, and Chemical Environment and Sustained Operations on Systems in Combat (P^2NBC^2) program administered by the U.S. Army Chemical School at Fort McClellan. The proponent agency for this research is the Directorate of Combat Developments at the U.S. Army Air Defense Artillery School (USAADASCH) at Fort Bliss. A Memorandum of Agreement covering this research project was signed on 7 November 1991 by USAADASCH and ARI.

The results of this research were presented to Colonel Schnakenberg, Chairman, and members of the P^2NBC^2 Technical and Scientific Advisory Group as a final test report in December 1991. The final test report was evaluated by the proponent in an Abbreviated Operational Assessment (AOA) memorandum dated 31 March 1992. In this AOA, the proponent concurred with the results in the final test report.

EDGAR M. JOHNSON
Acting Director

STINGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT: THE EFFECT OF EXPERIENCE

EXECUTIVE SUMMARY

Requirement:

To quantify the extent to which Stinger team engagement performance is impaired by wearing MOPP4 chemical protective clothing. To determine if extensive prior experience with and training in MOPP4 will improve engagement performance.

Procedure:

A design was chosen to measure the effects on performance of wearing MOPP4 chemical protective clothing while minimizing possible contaminating effects of long duration sustained operations. The approach was to test each of two groups of Stinger teams under conditions of MOPP0 and MOPP4. The two groups differed widely in training and experience. The low experience group consisted of twelve teams recruited during their last week of advanced individual training. This group had been qualified on the Stinger weapon, on visual aircraft recognition, and had received 9 hours of instruction in MOPP. The high experience group consisted of twelve teams recruited from veterans newly returned from Operations Desert Shield and Desert Storm. In addition to individual and unit training, this group had received 1 hour of MOPP training every day for 7 months while in Southwest Asia. Both experience groups were tested according to the same methods and procedures in the Range Target System engagement simulation facility. No team in either group spent more than 3 hours in MOPP4. Measurements were recorded for engagement performance, stress, and workload.

Findings:

The engagement performance of Stinger teams was poorer when wearing MOPP4 than when wearing MOPP0 for both experience groups. Analysis of these results suggests that the performance degradation seen in MOPP4 was attributable to the properties of the gas mask. Engagement performance was better for the high experience group than for the low experience group regardless of MOPP condition. Reported stress and workload ratings were higher when Stinger teams wore MOPP4 than when they wore MOPP0.

Utilization of Findings:

The results of this research, as a final test report plus data, were provided to the Physiological and Psychological Effects of the Nuclear, Biological, and Chemical Environment and Sustained Operations on Systems in Combat (P^2NBC^2) program. Performance decrement data such as these are integrated into the P^2NBC^2 database for eventual incorporation into the Performance Assessment Model. Results of P^2NBC^2-sponsored tests are periodically published.

STINGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT: THE EFFECT OF EXPERIENCE

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STINGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT: THE EFFECT OF EXPERIENCE

Background

The adverse effects of wearing the Mission Oriented Protective Posture (MOPP) ensemble and the detrimental consequences on performance are well documented. The literature from 1980 to 1988 dealing with the effects of the chemical protective ensemble and extended operations on performance was summarized by Headley, Brecht-Clark, Feng, and Whittenburg (1988). Their review included mostly laboratory and small-scale field tests involving infantry performing sustained operations in temperate climates and moderate terrains.

Based on their review, Headley et al. (1988) arrived at several conclusions. They determined that communication in MOPP gear can be difficult, and that this difficulty is exacerbated by distance and noise. The authors further observed that soldiers will devise new ways to perform their tasks to overcome the effects of the chemical protective ensemble. They maintain, therefore, that training in MOPP gear is essential to prevent soldiers from using the battlefield as a place to improvise ways to carry out their duties. The reviewed studies provided evidence that practice in MOPP gear can reduce some of the performance decrements, specifically those associated with fine motor skills. Ultimately, according to Headley et al., most tasks can be performed in the MOPP ensemble, but completion times may be longer.

The performance decrements in MOPP4 described by Headley et. al. (1988) can result from a variety of factors such as loss of manual dexterity, degradation of reaction time, deterioration of psychomotor skills, impairment of speech intelligibility, and reduction of the visual field. In some cases, it has been found that a particular piece of the MOPP ensemble is directly and often times solely responsible for the observed performance decrement. For instance, the mask and hood worn as part of the MOPP gear is known to degrade vision and speech functions (Bensel, Teixeira, & Kaplan, 1987; Harrah, 1985; Kobrick & Sleeper, 1986; and Nixon & Decker, 1985).

One investigation (Harrah, 1985) of the effect of mask and hood on performance examined visual performance using three prototype XM40 protective masks in combination with M19 binoculars. Harrah recorded the field of view with each binocular-mask combination and the standoff distance from the soldier's eye to the mask lens to explore their relationship to scan time performance. He found that mean field of view decreased linearly as standoff distance increased. The decreased field of view resulted in an increase in the time required to scan the target area.

The elements of the MOPP4 ensemble (suit, gloves, boots, and mask) can act alone or in concert to impede body mobility, psychomotor coordination, and manual dexterity. While gloves generally make the greatest contribution to the performance decrement for tests of manual dexterity (Bensel, 1980; Bensel, et al., 1987; Johnson & Sleeper, 1986), reduced body mobility and impeded psychomotor coordination can result from various combinations of the components of the protective ensemble (Bensel, et al., 1987).

Although serious problems are associated with wearing MOPP gear, the effects of the chemical protective ensemble are different depending upon the task being performed. Some studies (e.g., Posen, Munro, Mitchell, & Satterthwaite, 1986; U.S. Air Force Tactical Warfare Center, 1981; and Glumm, 1988) have shown that performance in MOPP4 did not differ significantly from performance in MOPP0. In addition, they have also shown that even when MOPP4 performance is degraded, in some cases it is still well within military standards.

On 9 May 1984 the Army Vice Chief of Staff directed that a program be initiated to assess the Physiological and Psychological Effects of the Nuclear, Biological, and Chemical Environment and Sustained Operations on Systems in Combat (P^2NBC^2). Key objectives of this program are to (1) quantify the crew performance decrement experienced during operations on the integrated battlefield; (2) determine how the decrement affects AirLand Battle doctrine; (3) identify methods and procedures to reduce the decrement--including doctrine, training, organization, and materiel changes; (4) integrate performance decrement data into a database; and (5) develop and validate a Performance Assessment Model. Results of P^2NBC^2-sponsored tests are being used to provide planning and operational risk factor analyses to field commanders, to support the development of training programs, to develop doctrine and organization, and to influence the design and acquisition of materiel to improve the capability to conduct successful combat operations on a battlefield where NBC weapons are extensively and continuously employed.

The United States Army Research Institute (ARI) Fort Bliss Field Unit is conducting a program of research on Forward Area Air Defense (FAAD) performance in a chemical environment under the auspices of the P^2NBC^2 program. The ARI program addresses the P^2NBC^2 issues of performance degradation and psychological effects of the chemically contaminated environment by testing air defense soldiers in MOPP0 and MOPP4 under different environmental conditions. Unlike some other P^2NBC^2-funded research (c.f., Headley et al., 1988), this program does not investigate the effect on performance of wearing MOPP4 during sustained operations. ARI research participants never wear the chemical protective clothing longer than three hours. Rather, the focus of this program is to investigate the effects on performance of the MOPP4 clothing itself, separate from any effects caused by extended operations. For example, Johnson and Silver (1992) investigated the effects of MOPP4 gear and target cuing on aircraft engagements by novice Stinger teams. They found engagement performance to be degraded by wearing the MOPP4 chemical protective ensemble and improved by the addition of precise visual cues. Use of these cues substantially reduced the degradation due to wearing MOPP4. That is, the MOPP4 clothing itself degraded the performance of the novice Stinger teams--independent of any effect of sustained operations--and the addition of cues restored most of the loss. In addition, Stinger teams reported higher stress and workload levels in MOPP4 than in MOPP0 whether or not they were receiving visual cues.

This paper reports the results of another short-duration investigation of the effects of wearing the chemical protective ensemble on Stinger team engagement performance. As stated above, one of the conclusions drawn by Headley et al. (1988) was that practice in MOPP gear can reduce some of the performance decrement attributed to wearing MOPP gear. The research questions addressed in this experiment were these. To what extent is Stinger team performance harmed by wearing MOPP4? Is Stinger team performance in MOPP4 improved by extensive experience with the chemical protective clothing? The approach was to measure the engagement performance of each of two groups of Stinger teams both while dressed in the standard battle dress uniform (MOPP0) and while wearing the standard uniform plus full chemical protective clothing (MOPP4). The two groups differed substantially in their relative level of experience with MOPP. The Low Experience Group was a sample of Stinger teams from Advanced Individual Training (AIT). The High Experience Group was a sample of Stinger teams recently returned from Operations Desert Shield and Desert Storm. It was hypothesized that both groups would show a decrement in engagement performance under conditions of MOPP4 and that the High Experience Group would perform better than the Low Experience Group on measures of engagement performance. It was also hypothesized that participants would report greater levels of stress and workload when wearing chemical protective clothing.

It should be noted explicitly that the independent variable "experience level" was not manipulated directly, but was created indirectly by recruiting test participants from two groups who differed widely in experience in MOPP4 (i.e., AIT trainees versus Southwest Asia veterans). The High Experience Group, therefore, differed from the Low Experience Group in several ways, including: Age, rank, time in service, amount of Stinger training, amount of Stinger training in MOPP4, and total amount of time spent wearing MOPP4. All results attributed to experience level should be understood in light of the opportunistic nature of this independent variable. Thus, this research can be viewed as an attempt to quantify the relative cost in readiness of employing novice Stinger teams versus experienced Stinger teams in a chemical environment.

Method

Participants

Low Experience Group. Twelve Stinger teams from the 1st Battalion, 56th Air Defense Artillery (ADA) Regiment, 6th ADA Brigade served in this experiment during December, 1990. Each team consisted of two soldiers, a team chief and a gunner. The Military Occupational Specialty (MOS) for all soldiers was MANPADS Crewmember (16S). The mean age of soldiers was 19.0 years (median 18.0). All 24 participants were in their last week of AIT at Fort Bliss, Texas. All had been qualified on the Stinger weapon and in visual aircraft recognition. All participants had completed nine hours of MOPP training during AIT, of which three hours were dedicated to engagement training.

High Experience Group. Twelve Stinger teams from the 5th Battalion, 62nd ADA Regiment, 11th ADA Brigade served in this experiment during April and May, 1991. Each team consisted of two soldiers, a team chief and a gunner. The MOS for all soldiers was 16S. The mean age of soldiers was 22.6 years (median 23.0). The mean and median rank of soldiers was CPL. All 24 soldiers had just returned from Southwest Asia where they had participated in Operations Desert Shield and Desert Storm. All soldiers had received either MOPP training or operational experience in MOPP for at least one hour every day for the seven months they were stationed in Southwest Asia.

The Stinger Weapon

Stinger is a man-portable air defense weapon system. It is a shoulder-fired, infrared-homing (heat-seeking) guided missile. Stinger requires no control from the gunner after firing. It has an identification friend or foe (IFF) subsystem which electronically interrogates target aircraft to establish friendly identification. Stinger provides short-range air defense for maneuver units and less mobile combat support units. Stinger is designed to counter high-speed, low-level, ground-attack aircraft. It is also effective against helicopter, observation, and transport aircraft (Field Manual No. 44-18-1, 1984).

Gunners maintain proficiency by practicing with the Stinger Training Set Guided Missile (M134). Each training set consists of a tracking head trainer, five rechargeable batteries, an IFF simulator, and a storage container. The Stinger tracking head trainer (THT) simulates the actual live Stinger round in size, shape, weight, and feedback from engagement actions—except, of course, no missile is launched. The seeker head inside the THT is the same seeker head as inside the live missile. Thus, its audio feedback to the gunner while tracking the heat source of an aircraft is the same. The IFF simulator imitates the actual IFF subsystem in size, weight, cabling requirements, and provides the same audio feedback to the gunner. The Training Set Guided Missile was the weapon used during this research.

Additional Equipment

All soldiers wore the standard battle dress uniform plus pistol belt, load bearing equipment, canteen, and kevlar helmet during the MOPP0 condition. During the MOPP4 condition all of the above items were worn plus the chemical protective clothing. The chemical protective clothing consisted of gloves, overboots, overgarments (worn closed), and M40 mask and hood (worn closed). In addition, each team chief carried a set of 7 x 50 binoculars (M19).

The Range Target System (RTS)

Description. Air defense performance data were collected in the Range Target System (RTS), a FAAD engagement simulation facility. Air defenders employ their weapons in simulated engagement of subscale fixed-wing and rotary-wing aircraft. RTS is located in the desert near Condron Army Airfield at White Sands Missile Range, New Mexico. RTS is the third FAAD simulation facility developed by the USARI Fort Bliss Field Unit, having evolved from the Realistic Air Defense Engagement System (RADES) circa 1984-1985, and the multiple weapon RADES (MRADES) circa 1986-1989. RTS has been operational since 1989. Details as to the validation of this simulation facility can be found elsewhere (Barber, 1990a; Drewfs, Barber, Johnson, & Frederickson, 1988; Johnson, Barber, & Lockhart, 1988). To date, Vulcan, PIVADS, Chaparral, Stinger, and Avenger units have engaged aircraft in RTS.

RTS uses subscale rotary-wing (helicopter) and fixed-wing (airplane) targets. All targets represent US or Soviet aircraft. Aircraft are camouflaged, three dimensional, molded fiberglass replicas. They are either flown remotely according to prescribed flight paths and maneuvers, or pop-up from designated positions via pneumatic stand-lift mechanisms. The flying fixed-wing (FW) aircraft are remotely controlled by radio signals from expert pilots stationed in the test range. The pop-up, rotary-wing (RW) targets are positioned strategically behind sand dunes at scenario prescribed distances. Flying aircraft are tracked by a laser position-location system. All aircraft are fitted with a heat source which stimulates the infrared-radiation seeker of heat-acquiring missile systems such as Chaparral, Stinger, and Avenger.

Air defense weapons are transported to the RTS site and emplaced in a battle position. Weapons are cabled to the Data Acquisition Station (DAS) and signal taps are installed on key weapon pins. The DAS interrogates the weapon every 250 milliseconds to see if a gunner action has occurred. Gunner engagement actions are thus collected automatically and time coded with a resolution of 250 milliseconds. Team chief verbal actions, such as detection and identification, are recorded by a human data collector who enters keystrokes on a computer keyboard located at the weapon position. The DAS interrogates this keyboard every 250 milliseconds to see if a verbal action has occurred. In this fashion gunner and team chief engagement actions are entered into the trial database along with a time code--time in seconds from target availability--and a range code--range of target aircraft in kilometers from fire unit. Thus, at the end of each engagement trial a complete record of all engagement actions executed by the team is obtained. This record is mathematically processed in near real time and is available in the form of feedback a few seconds after the termination of each scenario trial. When a Stinger gunner fires, a mathematical model synthetically flies the missile out to known target position for target intercept (or miss) in real time. In this fashion the effects of a complete engagement can be determined ("kill" or "miss") without necessitating the dangers or expense of live fire.

The primary components of the Range Target System are the Flying Target System (FTS), the Pop-Up Target System (PTS), the Range Control Station (RCS), the Data Acquisition Station (DAS), and the Position Location Station (PLS). The RCS, DAS, and PLS components are described in greater detail in Barber (1990b). The PTS and FTS components, respectively, are described more fully in Berry and Barber (1990a&b). The FTS presents flying, scale models of fixed-wing and rotary-wing aircraft. In this experiment, the FTS presented one-seventh scale FW models of the US A-7 and A-10, as well as the Soviet Su-20/22 and Su-25. The PTS presents one-fifth scale models of rotary-wing aircraft. These helicopters pop-up, pneumatically, from defilade, hover for a scenario-specified period of time with the rotor turning, and then descend. Each PTS is computer controlled by radio-frequency instructions sent from the RCS. The RW models used in this experiment were the AH-1, AH-64, UH-1, Mi-8, Mi-24, and Mi-28.

The RCS is the station where voice communications, system test and calibration checks, initialization of the system, real-time functions, performance scoring, and printing of feedback are initiated. Control of the Range Target System during scenario presentation is located at the RCS. The DAS captures all of the team chief and gunner engagement task performance and weapon events as a function of elapsed time and aircraft range. Effects scoring and assessment of kills are also performed at the DAS. The DAS provides scenario feedback on these events. During testing of the Low Experience Group there were two separated weapon positions, each with its own DAS and data collector. During testing of the High Experience Group there were four separated weapon positions each with DAS and data collector. All DASs are controlled by the RCS and communicate with the RCS by radio. Prior to each trial, scenario information is down-loaded from RCS to DAS. After each trial, engagement data are up-loaded from DAS to RCS. The PLS is used to register (ground locate) the weapon, the pop-up helicopter stands, flying target launch positions, as well as the other RTS stations (RCS, DAS, and PLS). Also, it is used to track flying targets and determine their range throughout a scenario. The PLS is accurate to within one meter in three dimensional space. The PLS can automatically detect, acquire, and track flying targets. It can also be operated manually using its video display and trackball.

Measures of performance obtained from RTS. The Stinger teams were evaluated on the timeliness of their engagement actions. When or how quickly did the teams perform their tasks? This efficiency of engagement was determined by the fourteen Task Performance Measures defined in Table 1. Task Performance Measures (TPMs) were collected on a trial-by-trial basis. These measures describe the time elapsed or the target aircraft range when specific engagement actions were performed. For fixed-wing aircraft these TPMs are expressed in terms of the aircraft range in full-scale kilometers when the engagement actions occurred (e.g., detection range, identification range, fire range). Since RTS aircraft are subscale, all ranges are presented in terms of full-scale range equivalents by multiplying the measured range by the scaling factor. For rotary-wing aircraft, TPMs are expressed in terms of the elapsed time, in seconds, between two engagement actions (e.g., time from target available to detect, time from detect to identify, time from identify to fire).

The Stinger teams were also evaluated on the effectiveness of their engagement actions. What mission-related outcomes resulted from their actions? This effectiveness of engagement was calculated by the eight Summary Performance Measures defined in Table 2. Summary Performance Measures (SPMs) are derived from task actions by summing across trials. SPMs are expressed in terms of percentages (e.g., percent aircraft detected, percent hostile aircraft correctly identified, percent hostile aircraft attrition).

Procedure

The schedule of data collection activities is presented in Table 3.

Table 1

Task Performance Measures

Fixed-Wing Aircraft

Detection Range: Range of aircraft (in full-scale kilometers) at detect response ("target")

Identification Range: Range of aircraft at identification response (tactical ID "hostile" or "friendly")

IFF Range: Range of aircraft at push of IFF button

Acquire Range: Range of aircraft at weapon acquisition signal

Lock-On Range: Range of aircraft at press of uncage bar (which locks seeker onto target)

Fire Range: Range of aircraft at fire (trigger pull)

Rotary-Wing Aircraft

Time from Target Available to Detect: Time (in seconds) from instrument record of target available until detect response (target available is defined as that time when the target has risen far enough to be visible from the weapon positions)

Time from Detect to IFF: Time from detect response to push of IFF button

Time from Detect to Identify: Time from detect response to identification response

Time from Detect to Acquire: Time from detect response to weapon acquisition signal

Time from Acquire to Lock-On: Time from weapon acquire signal to press of uncage bar

Time from Lock-On to Fire: Time from press of uncage bar to fire (trigger pull)

Time from Identify to Fire: Time from identification response to fire

Time from Detect to Fire: Time from detect response to fire

Table 2

Summary Performance Measures

Percent Aircraft Detected: Number of aircraft for which a detect response is given, divided by the total number of aircraft presented

Percent Aircraft Correctly Identified: Number of aircraft for which a correct ID response is given, divided by the total number of aircraft detected

Percent Hostile Aircraft Correctly Identified: Number of hostile aircraft for which a correct ID response is given, divided by the total number of hostile aircraft detected

Percent Friendly Aircraft Correctly Identified: Number of friendly aircraft for which a correct ID response is given, divided by the total number of friendly aircraft detected

Percent Hostile Attrition: Number of hostile aircraft credited as killed, divided by the total number of hostile aircraft presented

Percent Fratricide: Number of friendly aircraft credited as killed, divided by the total number of friendly aircraft presented

Percent Hostiles Killed Prior to Ordnance Release: Number of hostile aircraft credited as killed prior to ordnance release, divided by the total number of hostile aircraft presented (Ordnance release is defined as approaching within two kilometers of weapon position for fixed-wing aircraft. Ordnance release is defined as 20 seconds after target availability for rotary-wing aircraft.)

Conditional Probability of Kill Given Fire (expressed in percent): Number of aircraft credited as killed (hostile plus friendly), divided by the total number of fire events (trigger pulls)

Table 3

Schedule of Data Collection Activities

Stinger Low Experience Group

	8 Dec	9 Dec	10 Dec
AM:	MOPP0	MOPP4	MOPP0
PM:	MOPP4	MOPP0	MOPP4

	15 Dec	16 Dec	17 Dec
AM:	MOPP4	MOPP0	MOPP4
PM:	MOPP0	MOPP4	MOPP0

Stinger High Experience Group

	30 Apr	1 May	2 May
AM:	MOPP4	MOPP0	MOPP4
PM:	MOPP0	MOPP4	MOPP0

AM = 0900-1200 hrs
PM = 1300-1600 hrs

Field testing. The AIT personnel were tested in the RTS during their last week of training. They were brought to the RTS site by an instructor who in no way interfered with the test or coached them during the test. The Southwest Asia veterans were brought to the site by USARI. When participants reported either to the test site or to the transportation pick-up point, USARI personnel briefed them in detail on the research, their roles in it, and the specific tasks they would perform. An outline of the briefing given to participants is provided in Appendix A. All personnel were members of preexisting teams. Teams determined their own individual duty assignments (i.e., team chief or gunner). Teams were assigned to weapon positions.

Typically, a new AIT graduate would not be a team chief. For purposes of this experiment, however, leader-gunner teams were a requirement. So trainees were chosen as "acting" team leaders. This did not prove to be a problem, procedurally, since the trainees were knowledgeable and eager to perform as team chiefs.

Once at a weapon position, each data collector reviewed the engagement actions with his team and showed them their sector of responsibility, left limit, right limit, and primary target line (PTL). Each team was responsible for defending the same 90 degree search sector. Procedures were employed to keep all weapon positions visually and aurally independent of one another to prevent cross cuing.

Each team received 13 data trials under conditions of MOPP0 and 13 under MOPP4. MOPP0 and MOPP4 trials occurred in a group either during the morning or during the afternoon. The schedule of MOPP0 and MOPP4 trials was counterbalanced across days of the experiment as presented in Table 3. Prior to each morning and afternoon session a practice trial was run which contained both a fixed-wing and a rotary-wing aircraft. Participants received feedback on their performance at the end of the day after they finished both the MOPP0 and the MOPP4 sessions.

The same 13 scenarios were presented to all teams both in the MOPP0 and the MOPP4 sessions--but in a different counterbalanced order. The counterbalanced ordering of scenario presentations varied both across sessions within a day and across test days. The counterbalancing scheme was constrained by the practical necessity not to have two fixed-wing trials back-to-back (i.e., to save preparation time). The 13 test scenarios are described in Table 4. These 13 scenarios presented the participating teams with a variety of aircraft targets. Scenarios varied in aircraft type, intent, model, number of aircraft per scenario, range, aspect angle, aircraft ingress azimuth, duration of availability, and level of difficulty.

All data were collected during Weapons Control Status Tight. This meant that soldiers were required to make their tactical identification based upon visual criteria (e.g., Soviet aircraft were hostile, US aircraft were friendly). All trials were alerted.

Each trial began when the data collector gave the team a verbal alerting message. This message stated that air activity was imminent and reminded the team of their Weapons Control Status (i.e., "Red! Tight!"). The data collector verbally signalled the end of a trial by alerting the team that the current air attack had subsided ("Return to Condition Yellow."). Each team was instructed in the discrete trial procedure employed and reminded of the trial-begin and trial-end signals.

Soldiers completed stress and workload questionnaires as part of field testing. The stress questionnaire (Self-Evaluation Questionnaire, Spielberger, 1983) was administered twice during each session--once just prior to beginning and again just after finishing each session. The workload questionnaire (TLX Rating Scales, NASA-Ames, 1986) was administered immediately after each data trial during both MOPP0 and MOPP4 sessions.

Table 4

Test Scenario Specifications

Scen. No.	No. Targ.	Type	Intent	A.C. Model	Cl. Az.	Degrees Aspect	KM Range	Pres. Order	Sec. Avail.	Level of Diff.
01	1	FW	F	A10	11	45	**	—	—	Medium
02	1	FW	F	A7	1	45	**	—	—	Medium
03	1	FW	H	Su25	11	45	**	—	—	Medium
04	1	FW	H	Su20/22	1	45	**	—	—	Medium
05	2	Mix	H	Su25	12	0	**	Simul	—	High
			H	Mi24	12	90	3.5*	Simul	50	High
06	1	RW	F	UH1	11	270	3.5*	—	50	Low
07	1	RW	F	AH1	12	315	3.5*	—	50	Low
08	1	RW	F	AH64	1	90	3.5*	—	50	Low
09	1	RW	H	Mi28	11	315	3.5*	—	50	Low
10	1	RW	H	Mi24	12	90	3.5*	—	50	Low
11	1	RW	H	Mi8	1	45	3.5*	—	50	Low
12	3	RW	F	UH1	11	270	3.5*	Simul	100	High
		RW	F	AH1	12	315	3.5*	Simul	100	High
		RW	F	AH64	1	90	3.5*	Simul	100	High
13	3	RW	H	Mi28	11	315	3.5*	Simul	100	High
		RW	H	Mi24	12	90	3.5*	Simul	100	High
		RW	H	Mi8	1	45	3.5*	Simul	100	High

** Target becomes available for engagement at a range of at least 16 kilometers. Target is within team's search sector but outside visual detection range. Target flies an ingressing pattern until reaching one kilometer from team, then turns and flies back to base.

* Target rises from stationary, defilade position to become available for engagement, hovers for predetermined number of seconds, then returns to defilade position.

The procedure followed during a data trial was this:

- Data collector shouts alert.

- Team members, sitting with their backs to the range between trials, stand up and take their positions--gunner shoulders Stinger while team chief searches sector for aircraft.

- Upon detection of aircraft, team performs standard tactical engagement sequence including team chief using binoculars to identify aircraft--if a multiple target scenario, the engagement sequence is repeated anew for each target.

- Team searches sector for aircraft until data collector shouts reduced alert status.

- Gunner returns Stinger to rack.

- Team members return to seats at weapon position.

- Finally, team chief and gunner complete workload questionnaire for the trial just finished.

At the end of the test day, after all trials and feedback, soldiers were given an outbriefing. (Time constraints prevented some soldiers from being interviewed.) During this informal interview, both team chiefs and gunners were given an opportunity to express their opinions concerning the MOPP4 clothing itself and their problems attempting to engage aircraft while dressed in this clothing. The results of these interviews plus observations by USARI test personnel are presented in Appendix B.

The design of this experiment was a mixed factorial with two levels of the MOPP factor (0 and 4) and two levels of the experience factor (low and high). The MOPP factor was a within subjects manipulation, with all participants receiving both the MOPP0 and the MOPP4 conditions. The experience factor was a between subjects manipulation, with all participants in the Low Experience Group being AIT trainees and all participants in the High Experience Group being veterans newly returned from Operations Desert Shield and Desert Storm.

Hypotheses

Air defense engagement tasks were expected to be performed less well under conditions of MOPP4 when compared to the MOPP0 conditions. Air defense engagement tasks were expected to be performed better by the High Experience Group than by the Low Experience Group.

Participants were expected to report greater stress during the MOPP4 conditions when compared to the MOPP0 conditions. Participants were also expected to report greater workload during conditions of wearing MOPP4.

Results

Engagement Performance

Data for fixed-wing Task Performance Measures (e.g., detection range, identification range, etc.) were aggregated across FW scenarios (Scenarios 1, 2, 3, 4, and the FW portion of 5) for each condition for each team. Data for rotary-wing Task Performance Measures (e.g., time from target available to detect, time from detect to IFF, etc.) were aggregated across RW scenarios (Scenarios 6, 7, 8, 9, 10, 11, and the first RW detected in Scenarios 12 and 13) for each condition for each team. Scores for each Task Performance Measure were aggregated across similar scenarios (either FW or RW) by taking the arithmetic mean of the engagement measures recorded in RTS.

Summary Performance Measures (e.g., percent aircraft detected, percent aircraft correctly identified, etc.) were calculated over relevant scenarios for each condition for each team. For example, FW percent aircraft detected was calculated over Scenarios 1, 2, 3, 4, and the FW portion of 5. RW percent aircraft detected was calculated over Scenarios 6, 7, 8, 9, 10, 11, 12, and 13. For another example, FW percent fratricide was calculated over Scenarios 1 and 2. RW percent fratricide was calculated over Scenarios 6, 7, 8, and 12. For SPMs (but not TPMs) all three RW targets in Scenarios 12 and 13 were included.

Engagement performance was analyzed by a mixed two factor Analysis of Variance (ANOVA). The within subjects factor was MOPP level. The between subjects factor was experience level. One such mixed ANOVA was performed for each of the measures of engagement performance using the SPSS/PC+ Advanced Statistics software package (Norusis, 1986, pps. B153-B181). The effect of experience was tested against between-subjects variability, while both the MOPP effect and the experience by MOPP interaction effect were tested against within-subjects variability. Due to the relatively small samples collected plus the notoriously large variability common to applied field research, alpha probabilities as high as ten percent will be reported for the engagement performance results. Due to the large number of measurements recorded, results (ranges, times, percentages) and analyses (*F*-ratios, *p*-values, etc.) will be presented in detail by conditions only where there were statistically significant differences.

Data presented in tables are the arithmetic mean (Mean), the standard deviation (*SD*), and the number (*N*) of data points (i.e., the number of teams) upon which these descriptive statistics are based. It will be noted that the number of data points for FW targets is smaller than the number for RW targets. This is because technical difficulties with the PLS prevented some teams from being given the FW scenarios. No make-ups were possible due to the tight schedule of testing. The difference in *N* between the AIT sample and the Southwest Asia sample for the RW scenarios (10 versus 12) reflects a loss of data for two teams due to rain.

Results for fixed-wing aircraft: Task Performance Measures. Positive ranges are incoming, negative ranges are outgoing. Generally, the greater the incoming ranges, the better the performance. The mean detection range over all conditions was 6.91 kilometers. The mean overall range for IFF interrogation was 6.07 kilometers.

Table 5 presents weapon acquisition range for the aircraft as a function of MOPP level and experience level. There was no effect of MOPP level [$F(1, 14) = 0.16$, $p > .10$]. Acquisition range was significantly greater for the High Experience Group (3.65 kilometers) than for the Low Experience Group (1.55 kilometers) [$F(1, 14) = 6.75$, $p < .05$]. There was no interaction between MOPP level and experience level [$F(1, 14) = 0.36$, $p > .10$].

Table 5

Acquisition Range in Kilometers for Fixed-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	2.04	1.07	3.55	3.75
SD	3.26	2.88	1.60	2.03
N	8	8	8	8

Note. Positive ranges are incoming.

Table 6 presents identification range as a function of MOPP and experience. Aircraft were identified at significantly greater range under conditions of MOPP0 (2.54 kilometers) than under conditions of MOPP4 (0.89 kilometers) [$F(1, 14) = 7.10$, $p < .05$]. Aircraft were also identified at significantly greater range by the High Experience Group (2.81 kilometers) than by the Low Experience Group (0.61 kilometers) [$F(1, 14) = 5.70$, $p < .05$]. Again, there was no interaction between MOPP level and experience [$F(1, 14) = 0.01$, $p > .10$].

Table 6

Identification Range in Kilometers for Fixed-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	1.45	- 0.22	3.63	1.99
SD	2.33	2.00	2.15	2.40
N	8	8	8	8

Note. Positive ranges are incoming; negative ranges are outgoing.

Table 7 presents the range at weapon lock-on as a function of MOPP level and experience level. There was no effect of MOPP level on lock-on range [$F(1, 14) = 0.09$, $p>.10$]. Lock-on was, however, performed at a significantly greater range by the High Experience Group (1.45 kilometers) than by the Low Experience Group (-0.97 kilometers) [$F(1, 14) = 4.61$, $p<.05$]. Again, there was no interaction between MOPP level and experience [$F(1, 14) = 0.36$, $p>.10$].

Table 7

Lock-On Range in Kilometers for Fixed-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	- 1.07	- 0.86	1.77	1.14
SD	3.04	2.15	2.69	2.64
N	8	8	8	8

Note. Positive ranges are incoming; negative ranges are outgoing.

Table 8 presents the range at fire as a function of MOPP and experience. There was no significant effect of MOPP level on fire range [$F(1, 14) = 1.59$, $p>.10$]. Fire was performed at a significantly greater range by the High Experience Group (0.32 kilometers versus -1.85 kilometers) [$F(1, 14) = 3.46$, $p<.10$]. There was no interaction between MOPP level and experience level [$F(1, 14) = 1.18$, $p>.10$].

Table 8

Fire Range in Kilometers for Fixed-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	- 1.79	- 1.91	1.13	- 0.49
SD	3.31	2.00	2.55	2.84
N	8	8	8	8

Note. Positive ranges are incoming; negative ranges are outgoing.

Figures 1 through 4 display the FW aircraft ranges for engagement events. Figure 1 displays the results for all conditions of the experiment. Figures 2 through 4 display subsets of these results which highlight key effects implicit in the analyses described above.

Figure 2 shows the range of engagement actions for the MOPP0 versus MOPP4 comparison for data summed over both experience groups. Performance on the identification task was significantly worse under conditions of MOPP4. Figure 3 shows the range of engagement actions for the comparison between the Low Experience Group and the High Experience Group for data summed over both conditions of MOPP. Performance was significantly better for the High Experience Group on the acquisition through fire tasks by a mean range of 2.22 kilometers.

Figure 4 presents a comparison between the Low Experience Group in MOPP0 and the High Experience Group wearing MOPP4. In this comparison, the MOPP4 condition was not inferior to the MOPP0 condition during any of the six engagement tasks. That is, the performance of the High Experience Group in MOPP4 was not degraded relative to the Low Experience Group in MOPP0. This figure provides an estimate of the extent to which the degradation attributable to wearing MOPP4 can be alleviated by extensive experience.

Results for fixed-wing aircraft: Summary Performance Measures. The mean percentage of aircraft detected over all conditions was 98.13. The mean conditional probability of a kill given fire summed over all conditions was 63.81 percent.

Table 9 presents percent aircraft correctly identified (hostile plus friendly) as a function of MOPP level and experience level. There were no statistically significant differences as a function of MOPP level [$F(1, 14) = 0.75$, $p > .10$]. Aircraft were identified correctly significantly more often by the High Experience Group (81.87%) than by the Low Experience Group (56.93%) [$F(1, 14) = 17.11$, $p < .001$]. There was no interaction between MOPP level and experience level [$F(1, 14) = 0.45$, $p > .10$].

Table 9

Fixed-Wing: Percent Aircraft Correctly Identified by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	56.37	57.50	77.50	86.25
SD	20.28	22.52	7.07	11.57
N	8	8	8	8

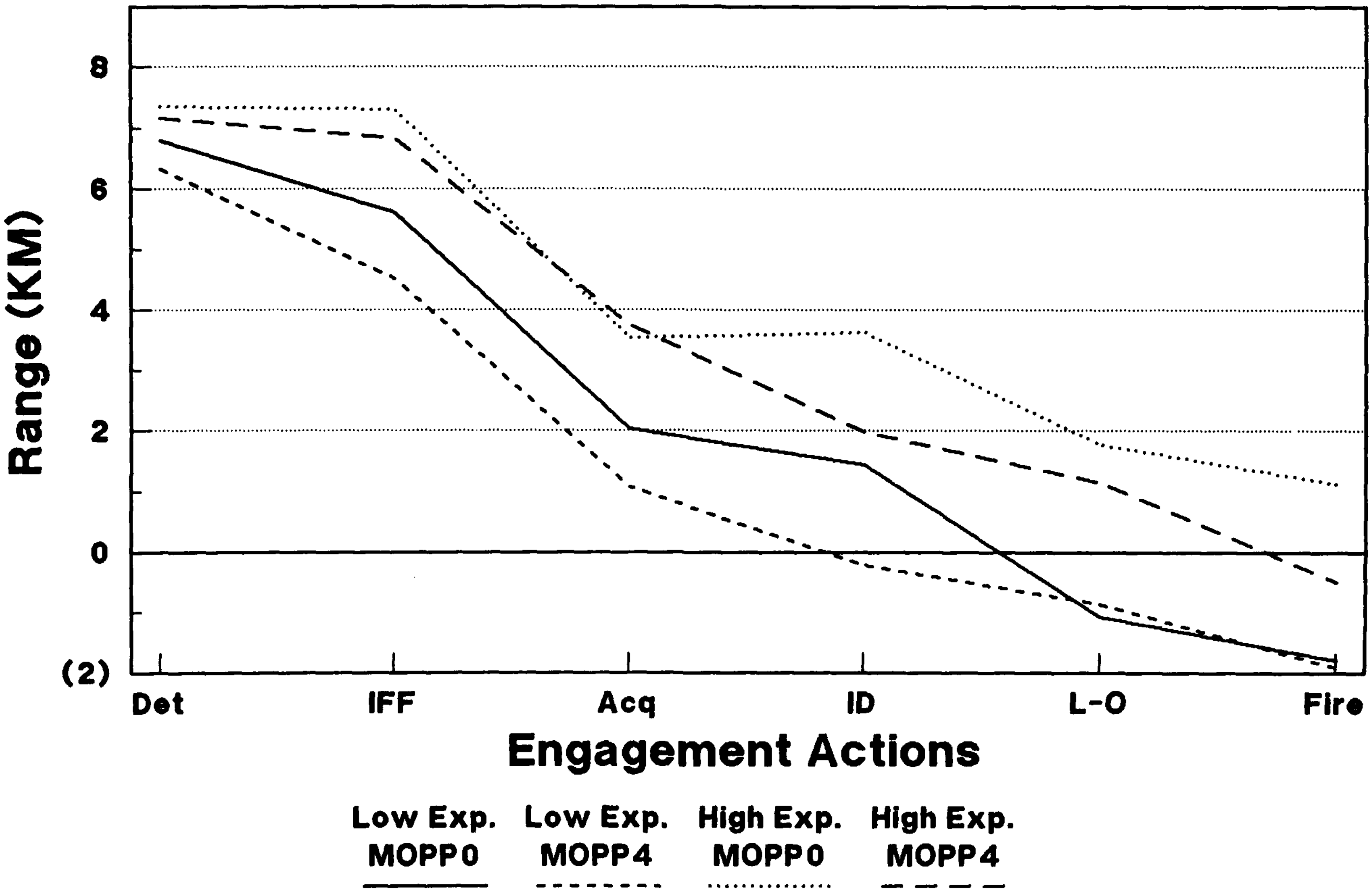

Figure 1. Range of engagement actions for fixed-wing targets: All conditions.

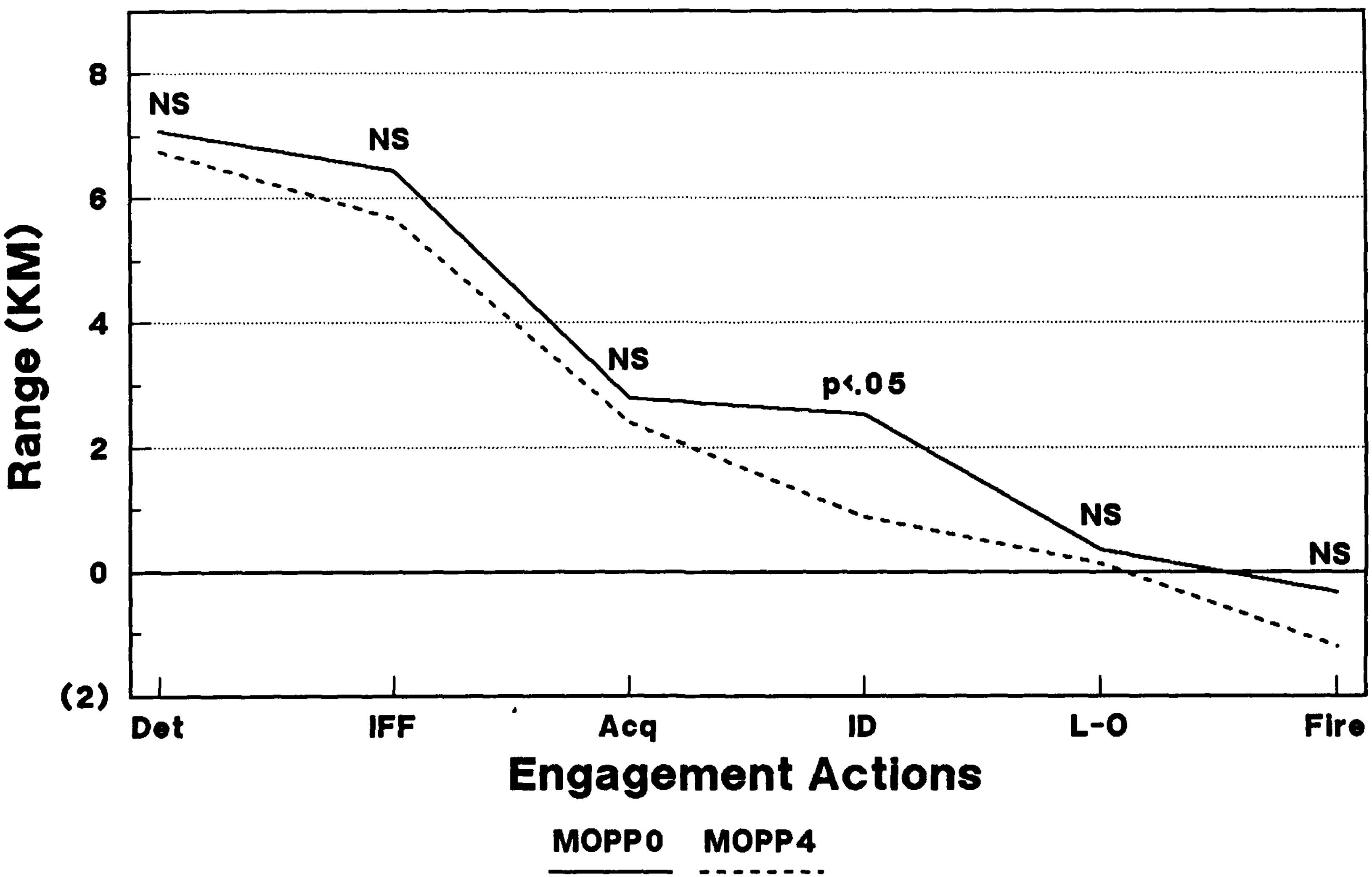

Figure 2. Range of engagement actions for fixed-wing targets: MOPP0 versus MOPP4 (summed over both experience groups).

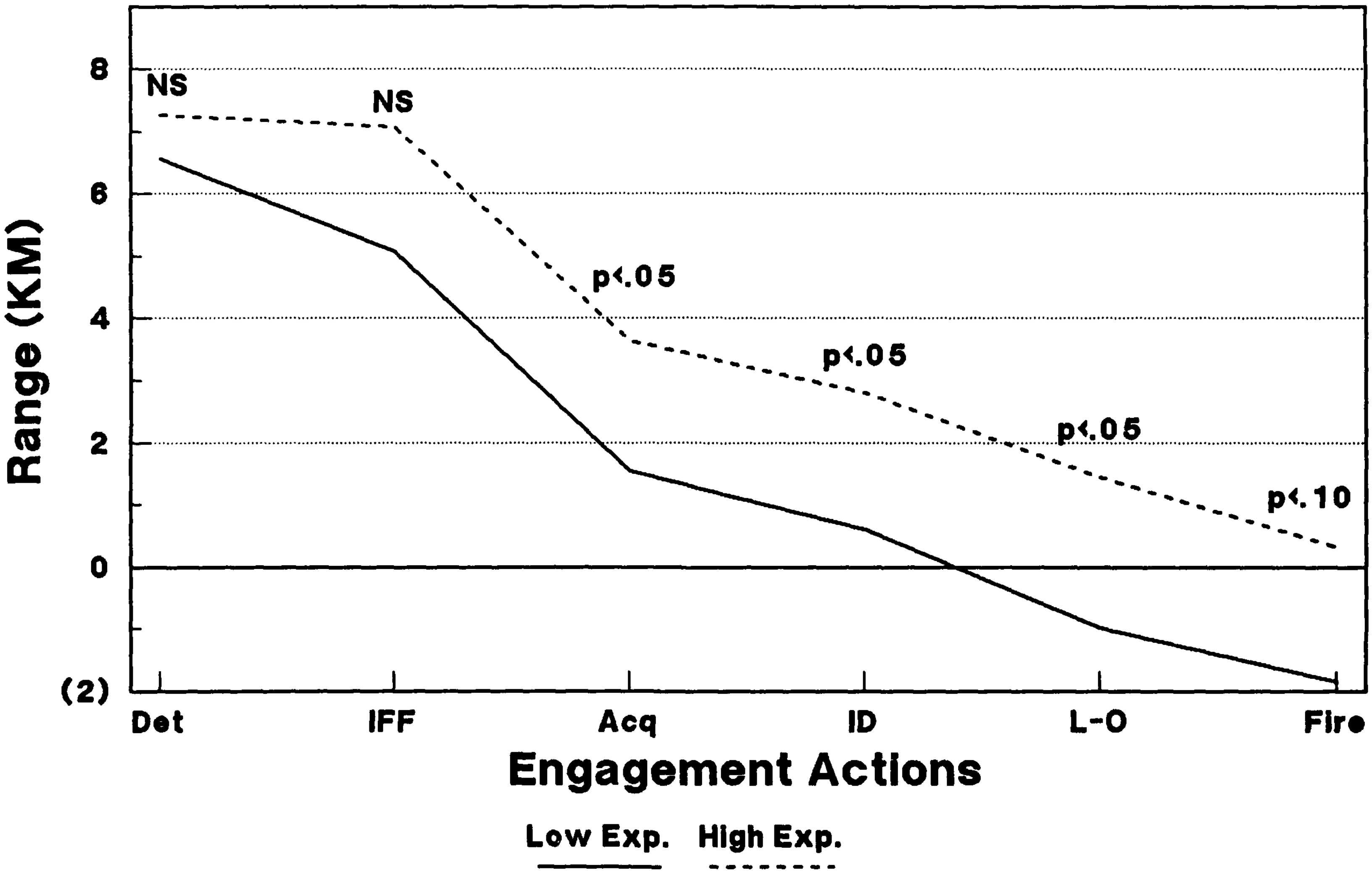

Figure 3. Range of engagement actions for fixed-wing targets: Low Exp. versus High Exp. (summed over both conditions of MOPP).

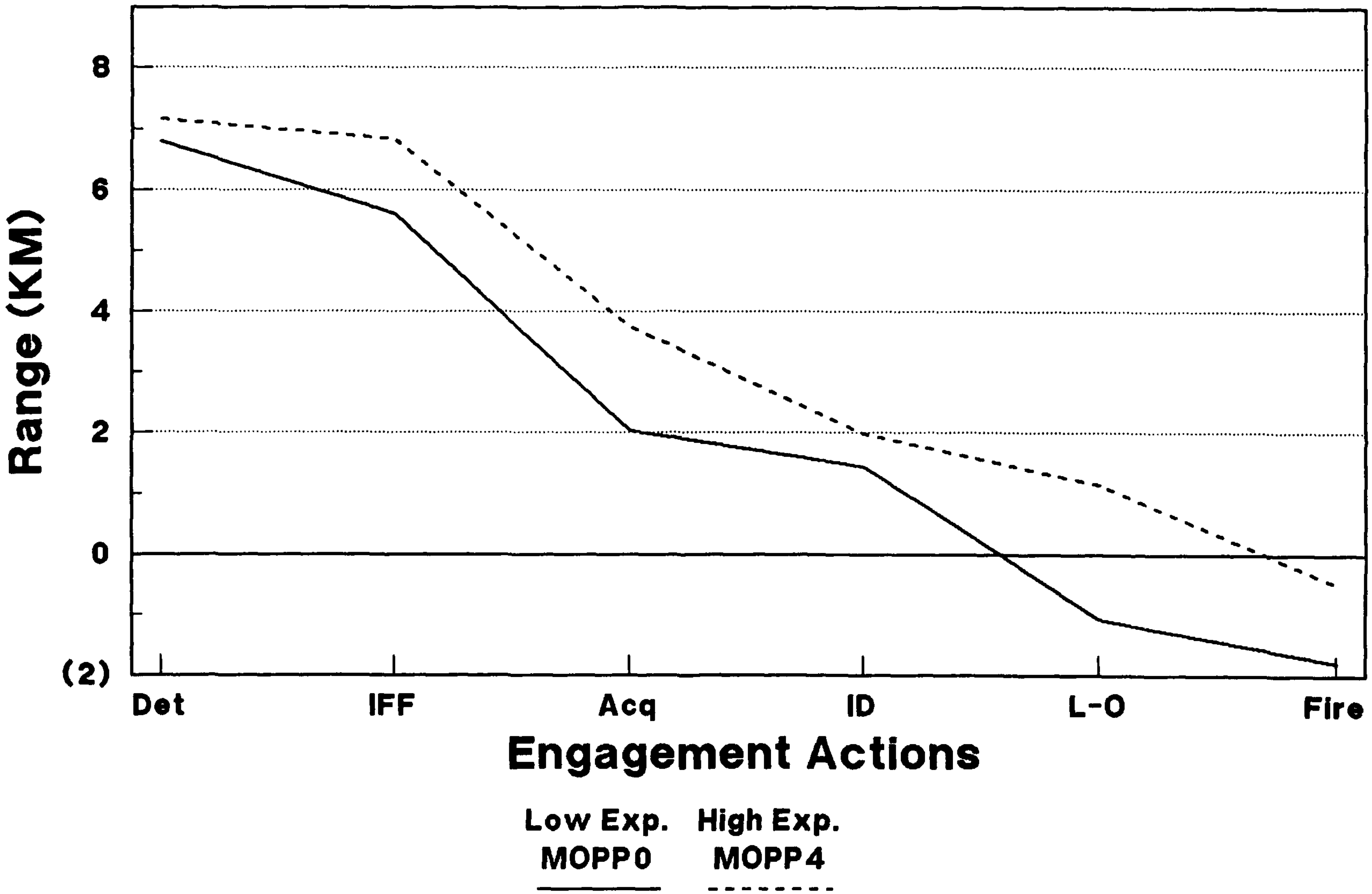

Figure 4. Range of engagement actions for fixed-wing targets: Low Exp. Group in MOPP0 versus High Exp. Group in MOPP4.

Table 10 shows percent friendly aircraft correctly identified as a function of MOPP level and experience. There was a statistically significant interaction between MOPP level and experience group [$F(1, 14) = 9.00$, $p<.01$]. For the AIT group their correct identification rate was higher for MOPP0 than MOPP4, whereas this was reversed for the Southwest Asia group. This nonintuitive reversal in correct identification rate can be traced to Scenario 2 which featured the friendly A7 aircraft. The Southwest Asia group consistently misidentified the A7 as "hostile" while in MOPP0, thereby lowering their percent correct rate for the MOPP0 condition. In addition, there was a significant main effect of experience [$F(1, 14) = 3.50$, $p<.10$], with the overall correct identification rate being higher for the High Experience Group (62.50%) than for the Low Experience Group (50.00%).

Table 10

Fixed-Wing: Percent Friendly Aircraft Correctly Identified by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	56.25	43.75	50.00	75.00
SD	17.68	17.68	0.00	26.73
N	8	8	8	8

Table 11 shows percent hostile aircraft correctly identified as a function of MOPP condition and experience level. There was no statistically significant difference in performance by MOPP level [$F(1, 14) = 0.52$, $p > .10$]. The correct identification rate was, however, significantly greater for the High Experience Group [$F(1, 14) = 10.26$, $p < .01$], being 95.87 percent correct overall for the Southwest Asia group and 59.31 percent correct overall for the AIT group. There was no interaction between condition of MOPP and level of experience [$F(1, 14) = 0.52$, $p > .10$].

Table 11

Fixed-Wing: Percent Hostile Aircraft Correctly Identified by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	52.00	66.63	95.87	95.87
<u>SD</u>	43.17	39.92	11.67	11.67
<u>N</u>	8	8	8	8

Table 12 displays hostile aircraft attrition aggregated over MOPP conditions and experience groups. There was no statistically significant difference in attrition between MOPP0 and MOPP4 [$F(1, 14) = 0.15$, $p > .10$]. Attrition was, however, significantly greater for the High Experience Group (73.00%) than for the Low Experience Group (32.31%) [$F(1, 14) = 7.89$, $p < .05$]. There was no interaction between MOPP and experience [$F(1, 14) = 0.87$, $p > .10$].

Table 12

Fixed-Wing: Percent Hostile Aircraft Attrition by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	27.13	37.50	75.13	70.87
<u>SD</u>	30.89	37.62	23.59	37.57
<u>N</u>	8	8	8	8

Table 13 displays the fratricide rate for friendly aircraft aggregated over the conditions of MOPP and experience. Fratricide rate was significantly greater in MOPP0 (37.50%) than in MOPP4 (15.63%) [$F(1, 14) = 12.70$, $p<.01$]. Again, this nonintuitive result can be traced to the A7 aircraft presented in Scenario 2. Both experience groups were more likely to identify the friendly A7 as "hostile" and fire at it in MOPP0 than in MOPP4, thus raising their fratricide rates. There was no significant difference as a function of experience level [$F(1, 14) = 0.10$, $p>.10$], and no MOPP by experience interaction [$F(1, 14) = 2.33$, $p>.10$].

Table 13

Fixed-Wing: Percent Fratricide by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	31.25	18.75	43.75	12.50
SD	25.88	25.88	17.68	23.15
N	8	8	8	8

Table 14 shows the percentage of hostile aircraft credited as destroyed ("killed") prior to ordnance release as a function of MOPP level and experience group. (The ordnance release point for hostile FW aircraft was defined as two kilometers from the weapon position. Killing an aircraft prior to ordnance release was defined as firing early enough in the engagement sequence to allow the missile time to intercept the flight path of the aircraft prior to the incoming aircraft reaching the two kilometer point.) There was a significant interaction between MOPP level and experience group [$F(1, 14) = 8.04$, $p<.05$]. The High Experience Group had a higher kill rate in MOPP0 than in MOPP4, whereas this was reversed for the Low Experience Group. This nonintuitive reversal for the Low Experience Group probably reflects nothing more than overall poor performance (i.e., a floor effect) since the mean kill rate for this group was only nine percent. There was also a significant main effect of experience level [$F(1, 14) = 3.46$, $p<.10$] with overall performance for the Southwest Asia group (31.13%) being better than that for the AIT group (9.37%).

Table 14

Fixed-Wing: Percent Hostiles Killed Prior to Ordnance Release by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	6.25	12.50	45.75	16.50
_SD_	17.68	24.87	39.66	17.64
_N_	8	8	8	8

Results for rotary-wing aircraft: Task Performance Measures. Generally, the shorter the engagement times, the better the performance. Table 15 presents the time from target available to detect as a function of MOPP level and experience level. Detection times were significantly longer during the MOPP4 condition (8.25 seconds) than during the MOPP0 condition (7.09 seconds) [$F(1, 20) = 6.44$, $p<.05$]. There was no statistically significant effect of experience level [$F(1, 20) = 0.10$, $p>.10$], and no interaction between MOPP level and experience [$F(1, 20) = 0.53$, $p>.10$].

Table 15

Time from Target Available to Detection in Seconds for Rotary-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	7.00	8.50	7.17	8.00
SD	0.82	2.37	0.72	2.05
N	10	10	12	12

Table 16 shows the time from detection to identification (ID) as a function of conditions of MOPP and experience. Times from detect to ID were significantly longer in the MOPP4 condition (10.61 seconds) than in the MOPP0 condition (8.83 seconds) [$F(1, 20) = 4.89$, $p<.05$]. There were no statistically significant differences as a function of experience level [$F(1, 20) = 0.17$, $p>.10$], nor was there a MOPP by experience interaction [$F(1, 20) = 0.02$, $p>.10$].

Table 16

Time from Detection to Identification in Seconds for Rotary-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	9.00	10.90	8.67	10.33
SD	2.31	4.75	2.15	3.11
N	10	10	12	12

Table 17 displays the time from target detection to IFF interrogation by conditions of the experiment. Interrogation times were significantly longer in the MOPP4 condition (4.13 seconds) than in the MOPP0 condition (2.99 seconds) [$F(1, 20) = 2.99$, $p<.10$]. Interrogation times were significantly shorter for the High Experience Group (2.67 seconds) than for the Low Experience Group (4.45 seconds) [$F(1, 20) = 3.25$, $p<.10$]. There was no interaction between MOPP and experience [$F(1, 20) = 0.01$, $p>.10$].

Table 17

Time from Detection to IFF in Seconds for Rotary-Wing Aircraft by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	3.90	5.00	2.08	3.25
SD	2.77	3.53	1.51	3.14
N	10	10	12	12

Table 18 presents the time from detection to weapon acquisition as a function of MOPP level and experience. There was a statistically significant interaction between MOPP level and experience group [$F(1, 20) = 5.16$, $p<.05$]. The Low Experience Group showed a large increase in acquisition time for the MOPP4 condition (4.80 seconds--accounting for the significant main effect of MOPP level [$F(1, 20) = 7.85$, $p<.05$]), while the High Experience Group showed essentially no increase in acquisition time for the MOPP4 condition (0.50 seconds). There was no statistically significant main effect of experience level upon acquisition times [$F(1, 20) = 2.68$, $p>.10$].

Table 18

Time from Detection to Weapon Acquisition in Seconds for Rotary-Wing Aircraft by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	8.40	13.20	7.25	7.75
SD	3.78	7.48	3.77	5.17
N	10	10	12	12

The mean time from weapon acquisition to lock-on summed over all conditions was 4.09 seconds.

Table 19 displays the time from lock-on to fire as a function of MOPP level and experience level. Times were significantly longer for the MOPP4 condition (3.84 seconds) than for the MOPP0 condition (2.81 seconds) [$\underline{F}(1, 20) = 15.00$, $\underline{p}<.001$]. Times were significantly shorter for the High Experience Group (2.75 seconds) than for the Low Experience Group (3.90 seconds) [$\underline{F}(1, 20) = 4.79$, $\underline{p}<.05$]. There was no interaction between MOPP level and experience [$\underline{F}(1, 20) = 1.89$, $\underline{p}>.10$].

Table 19

Time from Lock-On to Fire in Seconds for Rotary-Wing Aircraft by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	3.20	4.60	2.42	3.08
SD	1.40	2.17	0.79	0.90
N	10	10	12	12

Table 20 presents the time from identification to fire as a function of MOPP level and experience group. Times were significantly longer in the MOPP4 condition (8.60 seconds) than in the MOPP0 condition (5.95 seconds) [$\underline{F}(1, 20) = 6.72$, $\underline{p}<.05$]. There was no significant difference as a function of experience group [$\underline{F}(1, 20) = 2.52$, $\underline{p}>.10$], and no interaction between MOPP level and experience [$\underline{F}(1, 20) = 2.60$, $\underline{p}>.10$].

Table 20

Time from Identification to Fire in Seconds for Rotary-Wing Aircraft by Conditions

	Low Experience		High Experience	
Statistic	MOPP0	MOPP4	MOPP0	MOPP4
Mean	6.40	10.70	5.50	6.50
SD	3.50	7.33	2.94	3.03
N	10	10	12	12

Table 21 presents the cumulative time of the engagement from detection to fire by conditions of the experiment. Times were significantly longer in the MOPP4 condition (18.16 seconds) than in the MOPP0 condition (14.10 seconds) [$F(1, 20) = 10.22$, $p<.01$]. There were no statistically significant differences in times as a function of experience level [$F(1, 20) = 2.58$, $p>.10$]. Also, there was no MOPP level by experience level interaction [$F(1, 20) = 1.67$, $p>.10$].

Table 21

Time from Detection to Fire in Seconds for Rotary-Wing Aircraft by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	15.20	20.90	13.00	15.42
SD	3.97	10.74	3.86	4.79
N	10	10	12	12

Summarizing the results presented in Tables 15 through 21 it can be seen that engagement actions required more time to be performed in MOPP4. Of the eight statistical tests of the MOPP0 versus MOPP4 differences in performance (one test each for eight TPMs), seven met the criterion for statistical significance. These differences can be seen when the results are presented in graphic format. Figure 5 displays the MOPP0 versus MOPP4 comparisons for all TPMs for data summed over both experience groups. Of the eight statistical tests of the low experience versus high experience differences in performance (one test each for eight TPMs), two met the criterion for statistical significance. Additional experience served to reduce some engagement times. This experience effect, however, was not pronounced. These results are presented graphically in Figure 6 for data summed over both conditions of MOPP.

An estimate of the effect of high levels of experience upon the reduction of the MOPP4 decrement is displayed graphically in Figure 7. This figure presents all eight engagement action times for the Low Experience Group in the MOPP0 condition, the Low Experience Group in the MOPP4 condition, and for comparison the High Experience Group in the MOPP4 condition. Note that the High Experience Group in MOPP4 required less time than the Low Experience Group in MOPP4 for seven of the eight engagement actions. The High Experience Group wearing MOPP4 required 5.48 seconds less time to perform the engagement sequence from detection to fire than did the Low Experience Group wearing MOPP4—a reduction of the MOPP4 decrement by 96.14 percent. That is, the MOPP4 decrement recorded for the Low Experience Group was almost entirely removed by the employment of Stinger teams who had received high levels of training in and experience with the chemical protective ensemble.

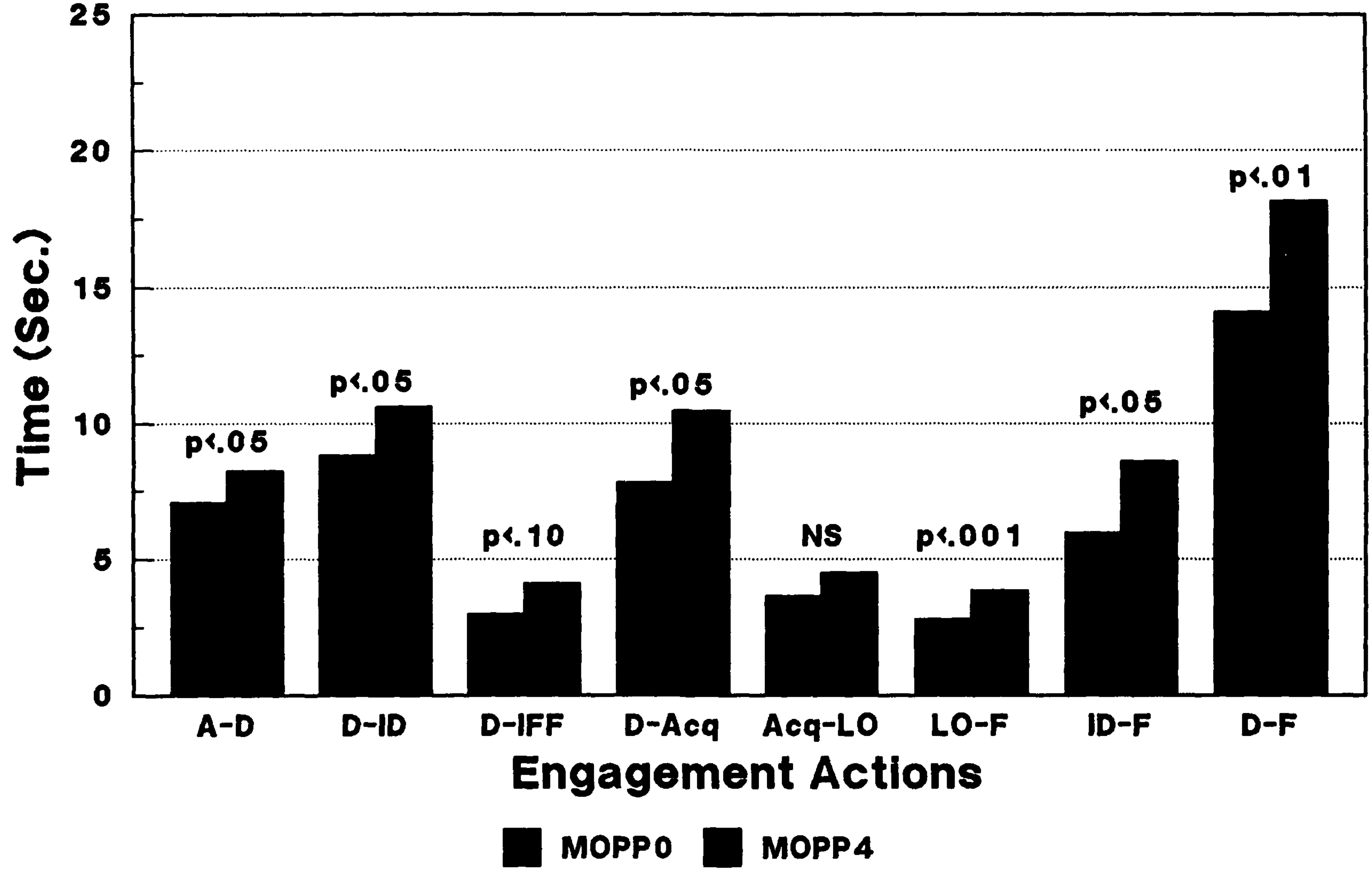

Figure 5. Time to perform engagement actions for rotary-wing targets: MOPP0 versus MOPP4 (summed over both exp. groups).

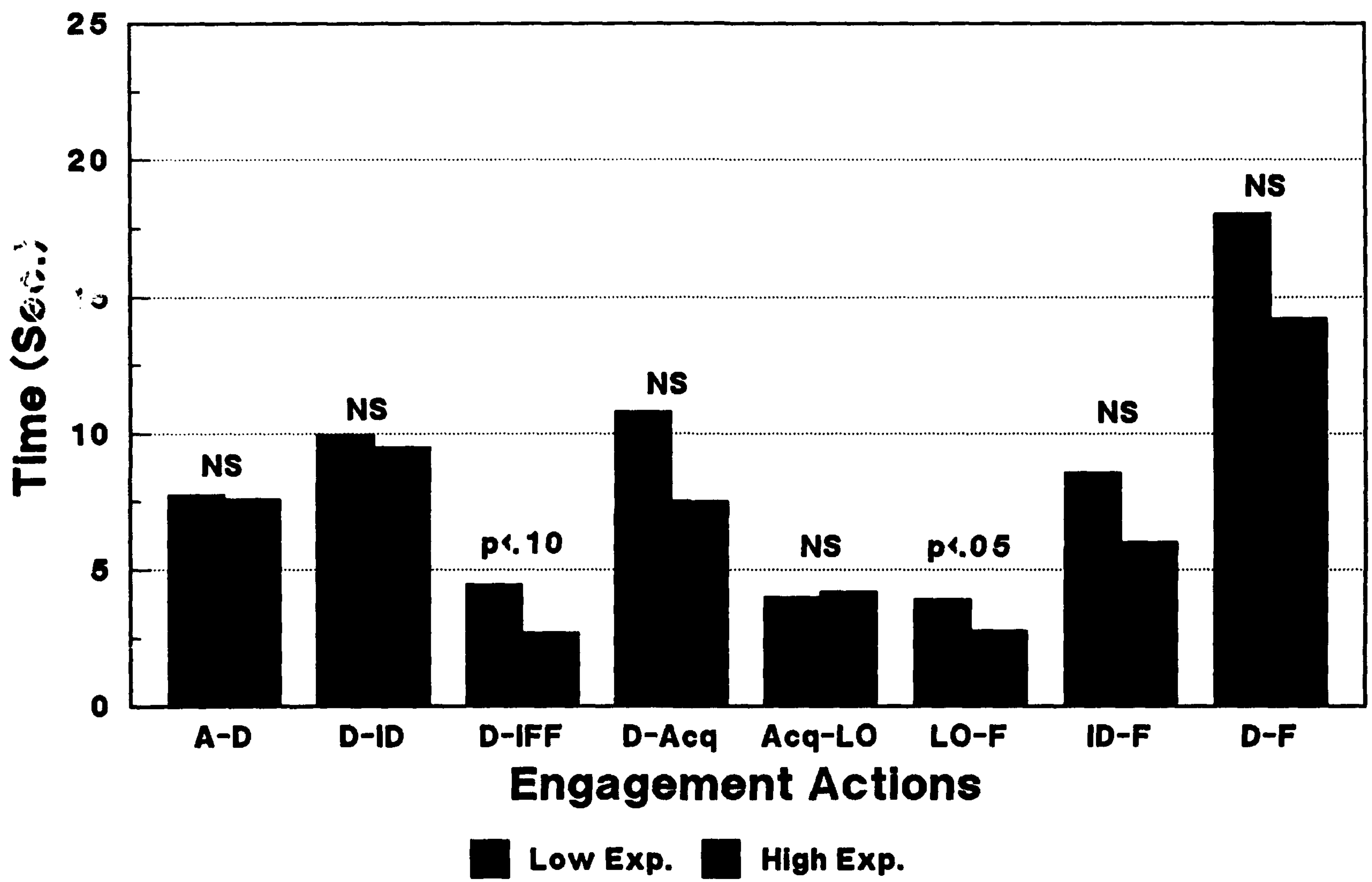

Figure 6. Time to perform engagement actions for rotary-wing targets: Low versus High (summed over both conditions of MOPP).

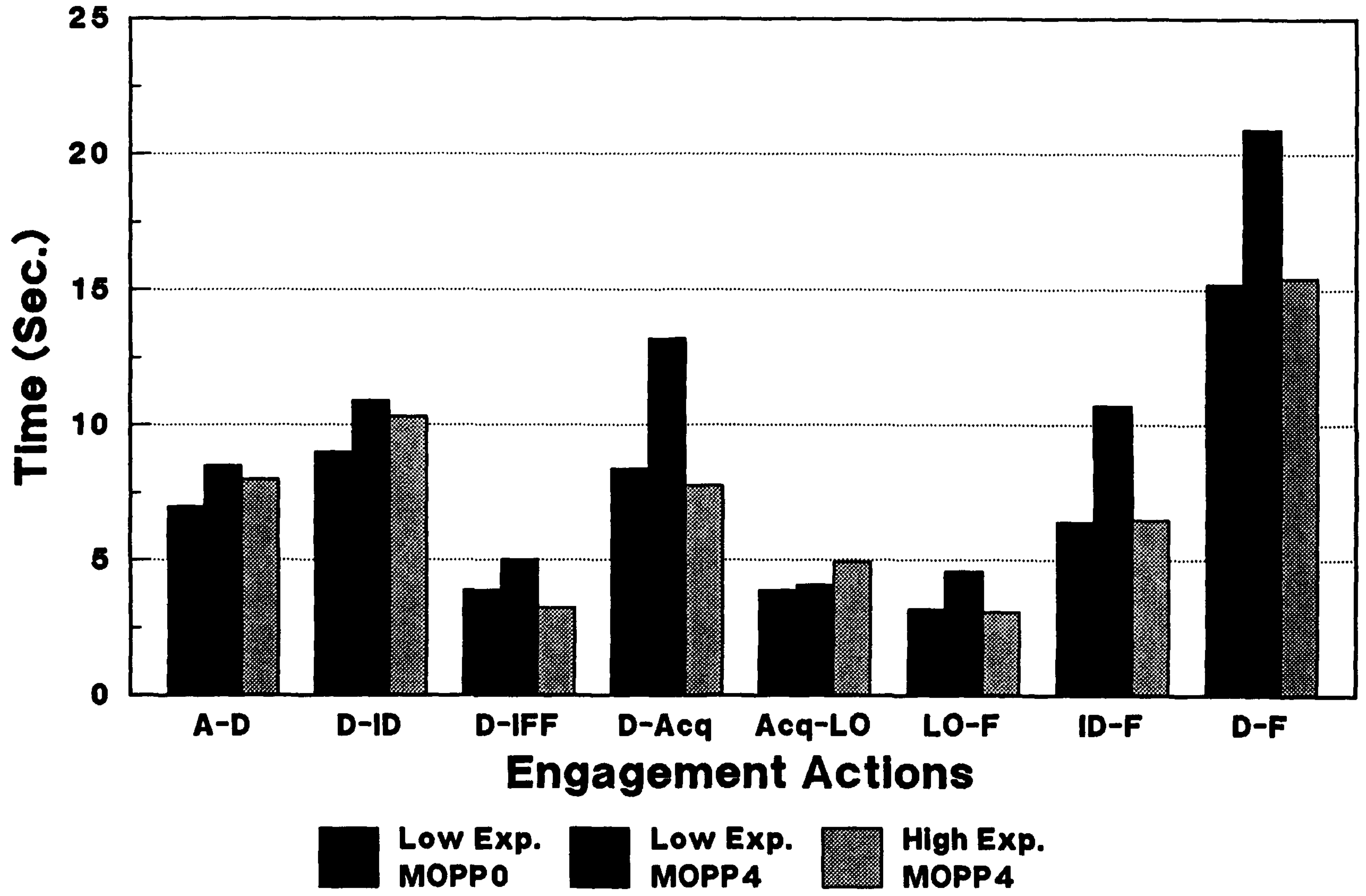

Figure 7. Time to perform engagement actions for rotary-wing targets: Effect of experience on reduction of the MOPP4 decrement.

Two special Task Performance Measures were analyzed--one each for Scenarios 12 and 13. Scenario 12 presented three friendly rotary-wing targets simultaneously for a total available duration of 100 seconds (see Table 4). Scenario 13 presented three hostile rotary-wing targets simultaneously for the same duration (see Table 4). In each scenario, the task was to process all three targets before they descended. These two scenarios were chosen for special analysis because they were high-difficulty, multiple-target scenarios and, therefore, were expected to tax the Stinger teams. Each of the two special measures was a record of the total time in seconds from initial target availability until the last action was performed on the third target. That is, each of these measures represents the total time required to service all three simultaneously-presented targets. The "last action" to be performed would be a cease fire for a third target identified as friendly and a fire for a third target identified as hostile. It was hypothesized that this "time from available to last act" would be longer for the MOPP4 condition and shorter for the High Experience Group.

The mean time from available to last act for Scenario 12 summed over all conditions was 47.76 seconds. Table 22 displays the time from available to last act for Scenario 13 for the conditions of the experiment. Times were significantly longer in the MOPP4 condition (59.34 seconds) than in the MOPP0 condition (51.61 seconds) [$\underline{F}(1, 20) = 9.93$, $\underline{p}<.01$]. There were no statistically significant differences in times as a function of experience level [$\underline{F}(1, 20) = 0.99$, $\underline{p}>.10$], and no interaction between MOPP and experience [$\underline{F}(1, 20) = 0.68$, $\underline{p}>.10$].

Table 22

Scenario 13: Time from Available to Last Act in Seconds by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	54.90	60.60	48.33	58.08
<u>SD</u>	10.43	13.98	11.04	12.78
<u>N</u>	10	10	12	12

<u>Results for rotary-wing aircraft: Summary Performance Measures</u>. The mean overall percentage of aircraft detected was 98.06. The mean overall percentage of aircraft correctly identified (hostile plus friendly) was 72.48. The mean overall percentage of friendly aircraft correctly identified was 57.91, while for hostile aircraft the percentage was 86.71.

Table 23 displays percent hostile aircraft attrition as a function of MOPP level and experience. Significantly more hostile aircraft were killed in MOPP0 (84.78%) than in MOPP4 (64.99%) [$F(1, 20) = 13.05$, $p<.01$]. There was no significant effect of experience level [$F(1, 20) = 0.23$, $p>.10$], and no MOPP by experience interaction [$F(1, 20) = 0.01$, $p>.10$].

Table 23

Rotary-Wing: Percent Hostile Aircraft Attrition by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	83.30	63.30	86.25	66.67
SD	22.25	24.67	16.99	15.83
N	10	10	12	12

Table 24 presents the percentage of hostiles credited as killed prior to their releasing ordnance by conditions of MOPP and experience. (The ordnance release point for hostile RW aircraft was defined as 20 seconds from availability. That is, a hostile aircraft was assumed to be capable of releasing ordnance if not killed prior to 20 seconds from availability. In order to prevent ordnance release the team must fire at the target early enough in the scenario to allow missile flight time to target within 20 seconds from availability.) The percent hostiles killed prior to ordnance release was significantly greater in MOPP0 (28.01%) than in MOPP4 (16.79%) [$F(1, 20) = 7.77$, $p<.05$]. There was no statistically significant difference as a function of experience level [$F(1, 20) = 2.59$, $p>.10$], and no interaction between MOPP and experience [$F(1, 20) = 0.13$, $p>.10$].

Table 24

Rotary-Wing: Percent Hostiles Killed Prior to Ordnance Release by Conditions

Statistic	Low Experience MOPP0	Low Experience MOPP4	High Experience MOPP0	High Experience MOPP4
Mean	22.70	10.00	33.33	23.58
SD	26.15	13.97	20.05	17.96
N	10	10	12	12

The mean fratricide rate over all conditions was 36.39 percent. The mean conditional probability of a credited kill given a fire was 97.20 percent.

Stress Ratings

The stress questionnaire (Self-Evaluation Questionnaire, Spielberger, 1983) was administered twice during each session—once just prior to beginning and again just after finishing each session. The Mann-Whitney U test for between-groups comparisons and the Wilcoxon T test for within-group comparisons (Bruning & Kintz, 1977) were used to analyze the stress ratings given by the Low and High Experience Groups. On three of four contrasts, the Low and High Experience Groups differed significantly from each other in reported stress levels (see Figure 8). Prior to MOPP0 and MOPP4 trials and at the conclusion of MOPP0 trials, the stress levels reported by the Low Experience Group were greater than those reported by the High Experience Group [Pretest MOPP0: $U(24, 24) = 122.5$, $p<.001$; Posttest MOPP0: $U(22, 24) = 161$, $p<.02$; Pretest MOPP4: $U(20, 24) = 129.5$, $p<.01$]. However, at the conclusion of the MOPP4 condition, stress levels were not significantly different between the two groups [Posttest MOPP4: $U(20, 24) = 219.5$, $p>.05$].

Both experience groups reported significantly higher stress levels before and after the MOPP4 condition when compared to the MOPP0 condition [Low Pretest MOPP0 vs. MOPP4: $T = 4$, $p<.005$, $N = 20$; Low Posttest MOPP0 vs. MOPP4: $T = 25$, $p<.005$, $N = 18$; High Pretest MOPP0 vs. MOPP4: $T = 35.5$, $p<.001$, $N = 24$; High Posttest MOPP0 vs. MOPP4: $T = 21$, $p<.0002$, $N = 24$]. Although reported stress was greater for MOPP4 than MOPP0, stress ratings did not increase significantly over the 13 trials in each clothing condition for either group [Low MOPP0 Pretest vs. Posttest: $T = 63$, $p>.05$, $N = 18$; Low MOPP4 Pretest vs. Posttest: $T = 63.5$, $P>.05$, $N = 20$; High MOPP0 Pretest vs. Posttest: $T = 118.5$, $p>.05$, $N = 24$; High MOPP4 Pretest vs. Posttest: $T = 102.5$, $p>.05$, $N = 24$, (see Figure 9)].

Workload

The workload questionnaire (TLX Rating Scales, NASA-Ames, 1986) was administered immediately after each data trial during both MOPP0 and MOPP4 sessions. The TLX workload ratings collected from the Stinger teams were used in the relative sense, comparing conditions to ascertain which were perceived as having higher workload. The workload data were subjected to a mixed, three factor, repeated measures Analysis of Variance (Norusis, 1986). Experience level (low, high) was the between-subjects factor. MOPP level (MOPP0, MOPP4) and scenario difficulty (low, medium, high) were the within-subjects factors.

There was no main effect of experience [$F(1, 30) = 1.74$, $p>.05$] indicating that reported workload was not different between the Low and High Experience Groups. The mean workload rating across these groups was 34.81. As expected, there was a main effect of MOPP [$F(1, 30) = 49.51$, $p<.001$] with workload ratings being significantly greater in MOPP4 (42.85) than in MOPP0 (26.77). There was also a significant scenario difficulty effect [$F(2, 60) = 12.86$, $p<.001$]. Participants responded differentially to scenario difficulty by assigning greater workload to the more demanding scenarios. The mean workload ratings were 30.84 for low difficulty scenarios, 34.22 for medium difficulty scenarios, and 39.36 for high difficulty scenarios.

The experience by MOPP [$F(1, 30) = 0.39$, $p > .05$], experience by scenario difficulty [$F(2, 60) = 1.17$, $p > .05$], and MOPP by scenario difficulty [$F(2, 60) = 1.00$, $p > .05$] interactions were not significant. However, the experience by MOPP by scenario difficulty interaction was significant [$F(2, 60) = 3.47$, $p < .05$].

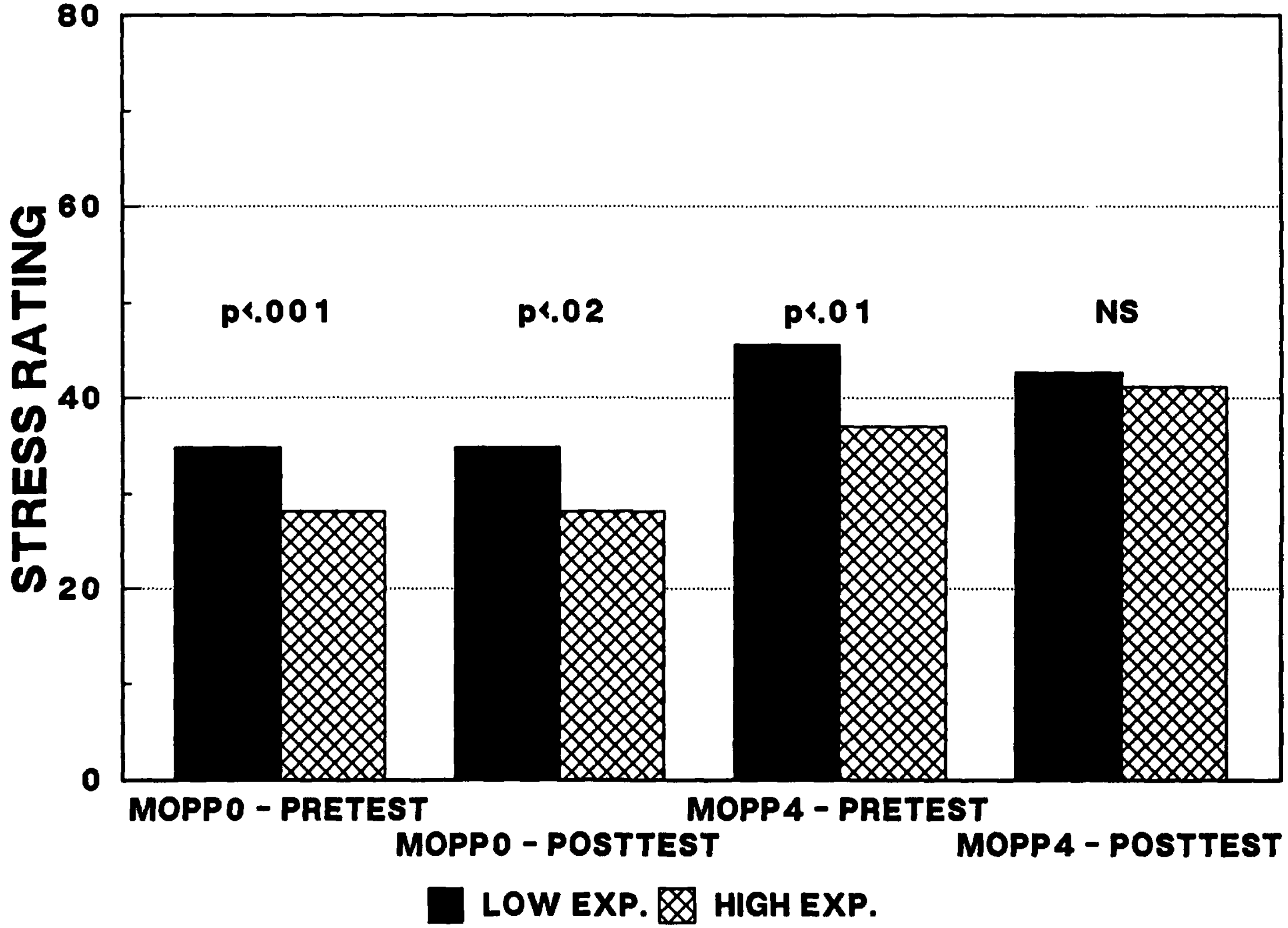

Figure 8. Stress levels reported by soldiers in Low Experience Group and High Experience Group before and after the MOPP0 and MOPP4 conditions.

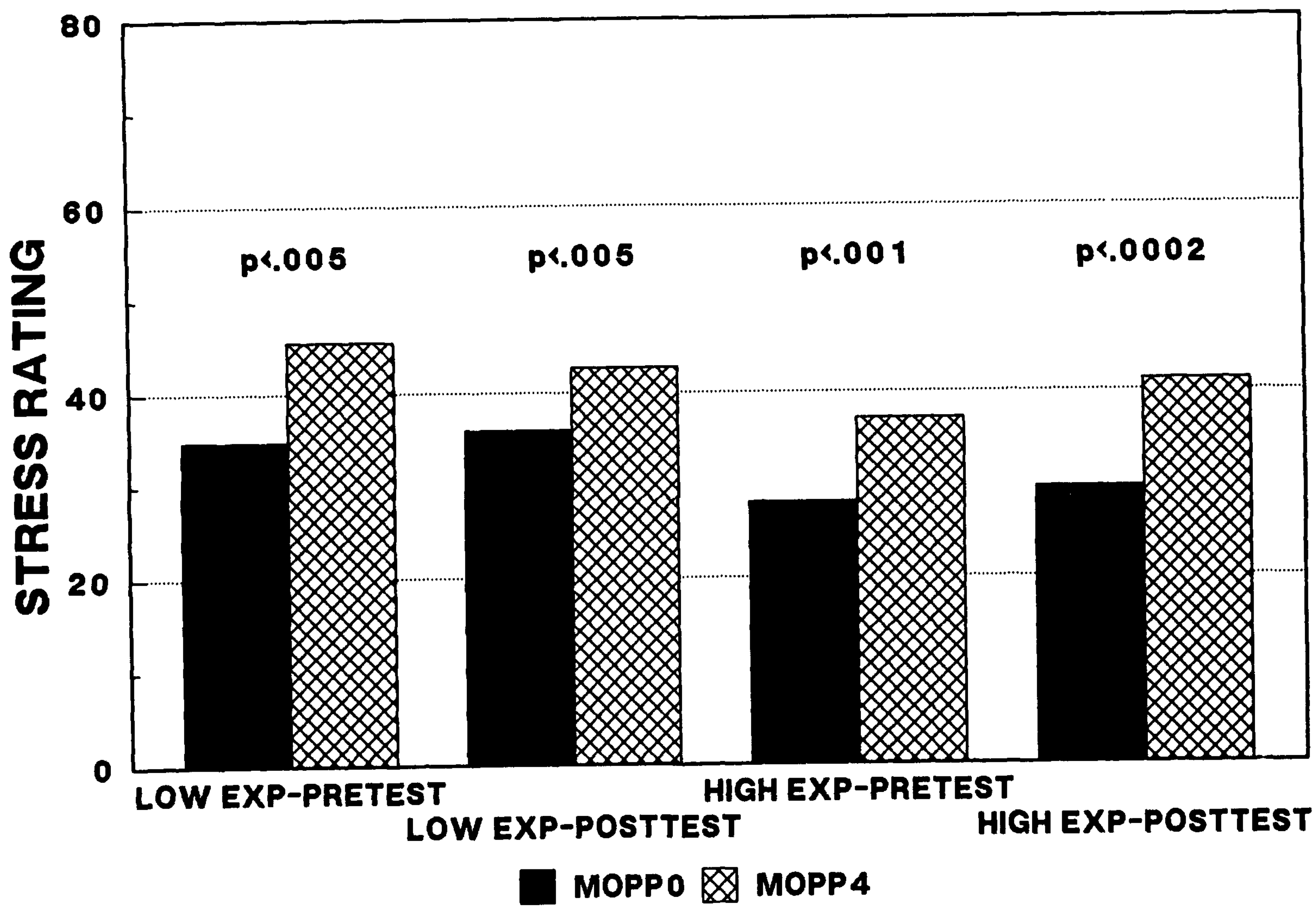

Figure 9. Comparison of MOPP0 and MOPP4 pretest and posttest stress means for both experience groups.

Discussion

Engagement Performance

Fixed-wing aircraft. The only statistically significant effect of wearing MOPP4 on FW task performance was to delay identification range by 1.65 kilometers. This decrement in identification range could have been caused by the difficulty team chiefs reported (see Appendix B) in attempting to identify flying aircraft with binoculars while wearing the mask. It has already been reported (Harrah, 1985) that the mask-binocular interface produces a narrow field of view. This narrow field of view makes tracking a maneuvering, flying aircraft difficult. In addition to this tracking problem, team chiefs reported double images. In an attempt to alleviate the double-image problem, team chiefs closed one eye or otherwise used only one optic of the binoculars.

The overall effect of high experience was to improve the range at which engagement events took place. Of the six engagement actions measured, the ranges of four (acquisition, identification, lock-on, and fire) were greater by a statistically significant amount for the High Experience Group. The mean improvement for these four tasks was 2.22 kilometers (see Figure 3). Note that this improvement attributable to increased experience did not occur early in the engagement sequence (detection), where performance is strongly influenced by visual sensitivity (Barber, 1990c), but later (acquisition through fire) where performance may be more strongly affected by increased knowledge, training, and skill.

Also, the High Experience Group identified both friendly and hostile aircraft more accurately, killed more hostile aircraft, and killed a greater percentage of these hostile aircraft prior to ordnance release. Thus, the High Experience Group were both more efficient and more effective at performing their engagement tasks than the Low Experience Group.

By providing Stinger teams with extensive experience wearing and training in the MOPP4 chemical protective clothing, is it possible to reduce the degradation in performance attributable to MOPP4? The answer appears to be a qualified yes. Compare the performance of the High Experience Group in MOPP4 with that of the Low Experience Group in MOPP0 (see Figure 4). The performance of the experienced group in MOPP4 showed no degradation whatsoever relative to the novice group in MOPP0. This conclusion is qualified, however, by the fact that these two groups of soldiers were chosen as the opportunity arose and, therefore, were not matched on all potentially relevant criteria.

Rotary-wing aircraft. Overall, the effect of wearing MOPP4 was to increase the time required for an engagement. Of the eight engagement actions recorded, seven required statistically significantly more time to be performed when wearing MOPP4 (see Figure 5). Over the engagement sequence from detection to fire, the extra time required for the MOPP4 condition was 4.06 seconds (see Table 21). This was a 29 percent increase (4.06 / 14.10 = 0.29).

Further, wearing MOPP4 harmed the engagement efficiency of both the team chief and the gunner. The engagement period detect to identify was entirely dependent upon the time taken by the team chief, using binoculars, to identify the target. The engagement period identify to fire was entirely dependent upon the gunner. The effect of wearing MOPP4 was to increase the time required by both members of the team. There was no evidence in these data that the effects of wearing MOPP4 were limited to a single "bottleneck" in the engagement sequence.

Specifically, what was it about wearing MOPP4 that caused this degradation in RW engagement performance? The increased time from available to detect was most likely caused by the restricted field of view of the mask (Bensel et al., 1987; Kobrick & Sleeper, 1986). The increase in detect to identify time could have been caused by the difficulty team chiefs reported (see Appendix B) in attempting to use the binoculars with the mask. Team chiefs reported a double-image problem with consequent visual disorientation and "solved" it by using only one eye. This could have delayed identification of the RW aircraft which, being 3.5 kilometers distant, were not identifiable without magnification.

At least part of the increase in time from identify to fire could have been caused by the difficulties reported by gunners (see Appendix B) in attempting to use the Stinger sight reticle while wearing the mask. Gunners reported difficulty acquiring aircraft in the reticle while wearing the mask. Perhaps more importantly, gunners reported difficulty inserting superelevate and lead angle because the mask prevented them from seeing the superelevate and lead reticles in the sight. This interpretation is supported by the significant increase in times from lock-on to fire shown for the MOPP4 condition (Figure 5 and Table 19). Insertion of the superelevate and lead angle takes place between lock-on and fire. Thus, it is a reasonable assumption that the primary cause of the performance degradation shown for RW aircraft in this experiment was the mask.

Under conditions of MOPP4 the percentage of hostiles killed was lower and the percentage of hostiles killed prior to ordnance release was lower. These results can be explained in terms of the increased time required for engagements in MOPP4. The more time the engagement sequence requires, the greater the probability that the hostile aircraft will have released its ordnance and then have returned to its defilade position, thereby being unavailable to kill. Thus, wearing MOPP4 harmed both engagement efficiency and engagement effectiveness.

Stress And Workload

Compared to the MOPP0 condition, participants reported both greater levels of stress and greater levels of workload when wearing the chemical protective clothing. This was true both for the Low Experience Group and for the High Experience Group.

The statistically significantly different stress ratings given by the Low Experience Group prior to MOPP0 and MOPP4 trials and after MOPP0 trials likely reflect their minimal experience, their uncertainty about acting as a team, and also their apprehension about performing in the chemical protective clothing. The non-statistically-significant stress levels reported by both groups at the conclusion of the sequence of MOPP4 trials may suggest that wearing MOPP4 gear is a stressful event regardless of the extent of prior experience with the clothing.

The higher workload reported by both the Low and High Experience Groups while wearing MOPP4 gear appears to have as its source the reduced field of view created by the chemical protective mask. The lenses of the gas mask produce a stand-off problem for both the team chief and gunner which reduces the field of view when the mask is used in conjunction with the M19 binoculars and Stinger sight. The reduced field of view makes it much more difficult to perform the tasks of the engagement sequence such as detecting, tracking, and identifying targets.

Although the rubber gloves initially interfered slightly with manual dexterity, they did not appear to create serious problems for either the team chief or gunner. The overgarment and boots were reported as being uncomfortable and awkward, but again, they did not produce serious or persistent problems for the teams.

Examination of the statistically significant interaction of experience, MOPP level, and scenario difficulty (see Figure 10) revealed that the level of workload reported by the High Experience Group increased as scenario difficulty increased under both clothing conditions. This was not true for the Low Experience Group, however. Under conditions of MOPP0 this group viewed the low and medium difficulty scenarios as being of equal and relatively low workload, while under conditions of MOPP4 they viewed all the scenarios as being of nearly equal and relatively high workload.

These results are understandable when one takes into consideration that the soldiers in the Low Experience Group were working together as team chief and gunner for the first time and that they had minimal training in the chemical protective clothing. In this experiment, the soldier of low experience who was not encumbered by a gas mask found one target scenarios, whether they consisted of fast moving or static scale models, to be equally easy. However, when encumbered by the gas mask and handicapped by the field of view problem it created, this same soldier found the engagement of all targets in all scenarios to be relatively difficult.

However, neither the behavior of the participants during this experiment, nor the resultant data suggest that the amount of stress and workload experienced by either group was excessive. All participants finished the sequence of MOPP4 trials uneventfully. No individual needed to remove his protective gear during the sequence of trials nor did anyone request to be withdrawn from the experiment. It is very important to recall here, however, that these data were collected under benign environmental conditions where participants were not subjected to heat stress, to movement stress, or to sustained operations.

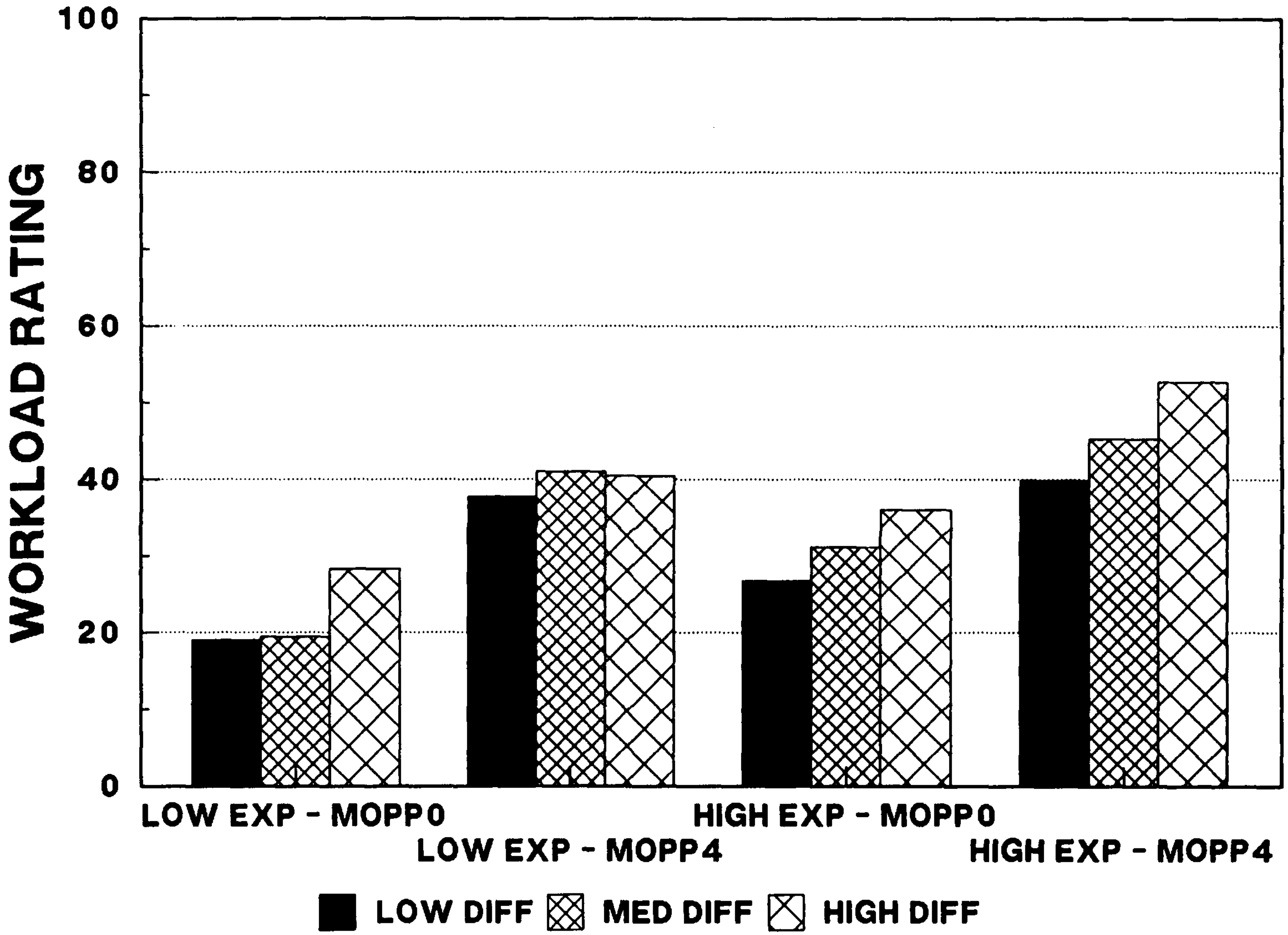

Figure 10. Interaction of experience level, MOPP gear, and scenario difficulty.

Conclusions

The engagement performance of Stinger teams was degraded by wearing the MOPP4 chemical protective ensemble. The visual identification range for fixed-wing aircraft was decreased by 1.63 kilometers. The time required to complete an engagement of a rotary-wing aircraft was increased by 4.06 seconds or 29 percent. Wearing the chemical protective clothing adversely affected the performance of both team chiefs and gunners. The article of MOPP4 clothing responsible for this reduction in engagement efficiency was judged to be the gas mask.

Stinger teams were less effective in performing their air defense mission while dressed in MOPP4. When engaging rotary-wing aircraft under conditions of MOPP4, Stinger teams killed a lower percentage of hostiles overall and killed a lower percentage prior to ordnance release.

The engagement performance of the High Experience Group (veterans of Operations Desert Shield and Desert Storm) was better than that of the Low Experience Group (AIT trainees) both in MOPP0 and MOPP4. The overall effect of high experience on the engagement of fixed-wing aircraft was to increase the range at which engagement events occured. The veterans acquired, identified, locked-onto, and fired at fixed-wing aircraft an average of 2.22 kilometers earlier than the trainees. This improvement in engagement efficiency was attributed to their extensive training with and experience wearing MOPP4. The veterans also performed their air defense mission more effectively by identifying aircraft more accurately, killing a greater percentage of hostiles, and killing a greater percentage of these hostiles prior to ordnance release.

Reported stress levels were higher when Stinger teams wore MOPP4 than MOPP0. Reported workload levels were higher when Stinger teams wore MOPP4 than MOPP0.

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Appendix A

Outline of Participant Briefing

1. Who we are: USARI.

2. What we do: Applied human performance research related to performance evaluation, training, aptitude measurement, and MOS classification.

3. Present project: Collect performance data from Stinger teams under conditions of wearing or not wearing chemical protective clothing. Data will be collected in the Range Target System. Proponent for this research is Directorate of Combat Developments, US Army Air Defense Artillery School. Sponsor for this research is Directorate of Combat Developments, US Army Chemical School.

4. Your job:
   (a) Engage aircraft using the Stinger THT under conditions of MOPP0 and MOPP4.
   (b) Fill out self-evaluation questionnaire and workload questionnaire.

5. What is RTS? Engagement simulation. Air defenders, with their air defense weapon systems, in field environment, in simulated engagement of subscale friendly and hostile fixed-wing and rotary-wing aircraft. Weapons are connected to RTS computer network. Gunner events recorded automatically via voltage taps on key weapon pins. Team chief verbal responses (detect, ID, command engage, or cease engagement) recorded by data collector at weapon position. Data collected are engagement times, engagement ranges, and percent correct actions. Laser Position Location System. Stinger missile math model. Give examples of performance measures.
   (a) Fixed-wing targets are flying scale models of US and Soviet attack jets.
   (b) Rotary-wing targets are static scale models of US and Soviet attack and utility helicopters, which pop-up from behind sand dunes, hover with rotor turning, and descend.

6. Weapon position: There are four separated weapon positions. Each team is responsible for 90 degree search sector. Left sector limit, right sector limit, and primary target line are marked. At each position: One team chief, one gunner, one Stinger THT cabled to RTS, and one data collector. Data collector is in communication with RTS Control. Data collector is not on your team, has a job to do, and will not help with your engagement.

7. Trials and procedures: Two data collection sessions in a day (one session in AM, one session in PM; one session is MOPP0, one session is MOPP4). Thirteen data trials and one practice trial per session. Always aircraft in a trial, no false alarms. Aircraft always in your search sector, no cheating on our part. We are only here to measure your performance wearing MOPP0 and MOPP4.
   (a) You will be in Weapons Control Status Tight: Positive visual ID required. Hostile criterion is aircraft origin; US models are friendly, Soviet models are hostile. Use aircraft silhouette for visual ID.

(b) Trial limits:

- Trial begins with alert message from your data collector ("Red Tight").
- Trial ends with change in alert status from your data collector ("Return to Condition Yellow").
- Between trials put Stinger THT down, sit with backs to range, fill out workload questionnaire.

(c) Aircraft:

- On any given trial you can expect to see fixed-wing, rotary-wing, or a mix of the two; friendly or hostile; single or multiple.
- Scenarios have been chosen to vary from easy to difficult.
- Remember to continue searching for aircraft until your data collector tells you that the trial is over.

8. Responsibilities:

(a) Team Chief:

- Detect plus clock azimuth plus point (say "target, 12 o'clock" and point with free hand). Do not use binoculars for detection, they will harm your performance.
- Visual ID, tactical ID (say "hostile" or "friendly"). Use binoculars for ID.
- Engagement or cease engagement command (say "engage" or "cease engagement").
- Control your gunner. It is your responsibility to hand off targets to gunner, to control the engagement, to be certain your gunner is engaging the target you have identified.

(b) Gunner:

- We want a complete engagement: IFF interrogation, Stinger activation, track, acquire, lock-on, superelevate, fire, or cease engagement, depending upon ID.
- One fire only per hostile target. Remember to recycle battery between target engagements.
- You are under team chief's control. Do not engage any target until ordered to do so.

(c) Both: Hand off targets to each other. You are a team, work together. If gunner detects a target before team chief, hand it off to team chief. If gunner knows aircraft ID, tell team chief.

9. Questionnaires:

(a) You will fill out two questionnaires—the self-evaluation questionnaire and the workload questionnaire. Give them examples of both.

(b) This is the self-evaluation questionnaire. It contains a series of statements. After reading each statement, you will decide how well it describes what you are feeling at that particular moment and fill in the appropriate circle. You will fill out this questionnaire four times, before and after both the MOPP0 and MOPP4 sessions. Do example. Questions?

(c) This is the workload questionnaire. We are going to ask you to fill out one after every trial today. You will see a line below trial number for scenario number. At the end of each trial, the data collector will tell you which scenario it was and you will place that number on the line. Using this questionnaire, we are asking you to tell us how much workload you experienced on that particular trial along six dimensions—mental demand, physical demand, temporal demand, performance, effort, and frustration. Place an "X" on the appropriate line along the scale for each dimension. Do example. Questions?

10. Feedback: You will receive feedback on your performance at the end of the day's activities, not trial by trial.

11. Safety: You are in the desert, so drink water whether you feel thirsty or not. If you run out of water we have more.

12. Anonymity: All research results are reported by unit designation only. Your personal anonymity is assured.

13. Questions?

14. Travel to weapon positions. Introduce each team to their data collector. Show team left and right sector limits and primary target line.

Appendix B

Performance Problems in MOPP4: Observations, Opinions of Soldiers, and "Work-Around" Solutions

M40 Mask And Hood

Problems using M19 binoculars with mask. All team chiefs interviewed (more than half were interviewed) reported problems using the binoculars with the mask. They reported tunnel vision; double vision; visual disorientation; difficulty tracking maneuvering aircraft with the small field of view available; cannot get the binoculars close enough to their eyes; eyepieces of binoculars slipped on surface of mask eyepieces. One of the authors experienced all of these problems when using the binoculars with the mask. The "work-around" solutions employed by team chiefs were to (1) close one eye, (2) close one eye and only look through one optic of the binoculars by turning them sideways, or (3) not use binoculars at all.

Problems using the Stinger sight with mask. All gunners interviewed (more than half were interviewed) reported problems using the Stinger sight with the mask. They reported difficulty tracking maneuvering aircraft with the tiny field of view available; cannot get the sight close enough to their eyes; cannot see any (or cannot see all three, or cannot see right-most) superelevate and lead reticles in the Stinger sight. One of the authors experienced all of these problems when using the Stinger sight with the mask. The "work-around" solutions employed by gunners were to (1) manually estimate the appropriate superelevate and lead angles before firing, or (2) slip the mask slightly (breaking seal!) in order to see the superelevate and lead reticles.

Miscellaneous problems. Communication problems were observed for, and reported by, the Low Experience Group (AIT). Stinger teams stand literally right next to each other during an engagement and communicate directly without aid of field telephone or radio. The communication problems were not in reception with the mask and hood on but in transmission with the mask and hood on. The mask distorted, muffled, and attenuated the sound of the speaker. Soldiers experienced no difficulty whatsoever hearing and understanding USARI test personnel who were not speaking through a mask, but even unmasked USARI test personnel had difficulty understanding masked test participants when they were speaking. One of the authors experienced this same problem when wearing the mask and hood. The "work-around" solution employed by soldiers was hand signals. Far fewer communication problems were observed for the High Experience Group (veterans of Operations Desert Shield and Desert Storm).

The veterans frequently reported that the rubber liner inside the M40 mask pressed on both sides of the bridge of the nose, squeezing the nose, and thereby restricting the passage of air and causing pain.

Gloves

Problem inserting IFF cable into gripstock of Stinger. Observed for all AIT gunners initially. Problem solved with experience over trials.

Problem turning paper pages with gloved hands. Observed for all soldiers. All soldiers eventually learned the "work-around" solution of using the eraser of a pencil to turn pages.

Overgarment

Gunners' pants frequently came unsnapped from jacket and slipped down. No solution found. The veterans reported that this problem was frequently observed during Operations Desert Shield and Desert Storm.