Technical Report 764

Effects of NBC Protective Equipment and Degraded Operational Mode on Tank Gunnery Performance

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Research Institute for the Behavioral and Social Sciences

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Tank gunner's performance in the M1 Unit Conduct of Fire Trainer (UCOFT) was tested while wearing Mission Oriented Protective Posture (MOPP) gear under normal and emergency operational mode conditions. A pretest, in both experiments, determined initial performance for possible use as a covariate on experimental test performance. In Experiment I, the subjects performed six different test exercises. Results of Experiment I indicated that MOPP gear and emergency operational mode degraded fire time, percent hits, and aiming error. MOPP gear and normal operational mode degraded aiming error only. The degradation in performance was dependent on the type of exercise. In Experiment II, the subjects performed four different test exercises. Results of Experiment II revealed degradation on all performance measures during emergency operational mode. No performance decrements were found for MOPP gear and no interaction between MOPP gear and operational mode occurred. The degradation in fire time and aiming error caused by emergency mode was dependent on the type of exercise. Multiple correlations between fire time and experience variables were significant, particularly overall time as a gunner.

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Training and Simulation

FOREWORD

The Fort Knox Field Unit of the Army Research Institute (ARI) conducts research in the areas of Armor training and simulation and soldier performance. The research is sponsored by the U.S. Army Armor Center and School (USAARMC & S) with the objective of increasing soldier readiness and operational effectiveness.

ARI's Fort Knox Field Unit provides research in identifying performance deficiencies associated with future battlefield conditions and extent of improvement in performance with training. Once deficiencies are identified, training countermeasures can be developed to offset the level of degradation and alleviate operational problems that may be present on the future battlefield.

The Command and Staff Department at the Armor School in Fort Knox and the U.S. Army Chemical School in Fort McClelland, Alabama, are proponents of Nuclear, Biological, and Chemical (NBC) simulation projects. This report on the effects of NBC equipment and operational mode on tank gunnery performance has been provided to these agencies. The research results were briefed to personnel from the Command and Staff Department, Armor School, and the Chemical School, Fort McClelland, in July 1987. Communication between agencies involved in NBC-related issues results in the identification of key research questions and answers. Consequently, coordinated efforts more rapidly advance today's understanding of training requirements for the future battlefield.

EDGAR M. JOHNSON
Technical Director

EFFECTS OF NBC PROTECTIVE EQUIPMENT AND DEGRADED OPERATIONAL MODE ON TANK GUNNERY PERFORMANCE

EXECUTIVE SUMMARY

Requirement:

The purpose of this research was to examine performance on the M1 Unit Conduct of Fire Trainer (UCOFT) by gunners wearing Mission Oriented Protective Posture (MOPP) gear, in normal and emergency operational conditions.

Procedure:

The research was conducted in two experiments. Subjects in Experiment I were assigned to one of four experimental groups: (a) Group 1--no MOPP, normal operational mode, (b) Group 2--mask only, normal operational mode, (c) Group 3--mask and gloves, normal operational mode, and (d) Group 4--mask and gloves, emergency operational mode. A pretest assessed initial performance for possible use as a covariate on experimental test performance. The pretest was performed without MOPP gear and in normal operational mode. The subjects completed six text exercises under the conditions corresponding to their assigned group. In Experiment II, a group of subjects that had performed exercises under emergency operational mode but without MOPP gear was combined with the previous Group 1, Group 3, and Group 4 from Experiment I. Experiment II was designed to assess the interaction between MOPP gear and operational mode. The pretest again assessed initial performance and was performed without MOPP gear, in normal operational mode. The subjects completed four test exercises in Experiment II under the experimental conditions for the assigned group.

Findings:

Results of Experiment I indicate that the combination of MOPP gear and emergency operational mode degraded fire time, percent hits, and aiming error, particularly in long-range target engagements. MOPP gear under normal operational mode conditions degraded aiming error only. The results of Experiment II revealed degradation on all performance measures by emergency operational mode. No performance decrements were found for MOPP gear, which did not further degrade performance under emergency operational mode. The degradation in fire time and aiming error caused by emergency mode was notably evident in long-range target engagements. Multiple correlations between fire time and experience variables were significant, particularly overall time as a gunner.

Utilization of Findings:

The results of this research revealed no overall substantial performance decrements for subjects wearing MOPP gear. These positive results may be the consequence of the stress on Nuclear, Biological, and Chemical (NBC) training

in today's Army. Performance degradation did occur when subjects performed under emergency operational conditions. Extensive training under degraded operational conditions appears mandatory to offset the performance deficiencies revealed in this research. For mission accomplishment, soldiers need to be trained during peacetime under all potential conditions faced on the modern battlefield. The UCOFT training matrix includes exercises specifically designed for training under various degraded operational conditions. Therefore, UCOFT training should be a critical component in training countermeasures to alleviate the level of degradation associated with future battlefield conditions.

EFFECTS OF NBC PROTECTIVE EQUIPMENT AND DEGRADED OPERATIONAL MODE ON TANK GUNNERY PERFORMANCE

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EFFECTS OF NBC PROTECTIVE EQUIPMENT AND DEGRADED OPERATIONAL MODE ON TANK GUNNERY PERFORMANCE

INTRODUCTION

The future battlefield may involve Nuclear, Biological, and Chemical (NBC) warfare. Soviet military doctrine encompasses the widespread and liberal use of chemical warfare, particularly in surprise attacks (Wagner & Gold, 1982). Given the likelihood of NBC warfare, soldiers must be prepared to use protective equipment in order to survive and sustain extended operations in an NBC environment. The concept of Mission-Oriented Protective Posture (MOPP) originated from the real need for mission accomplishment with as little reduction in combat effectiveness as possible under NBC conditions. MOPP can be raised or lowered through five levels from MOPP0 to MOPP4. The MOPP levels are defined by the amount of protective equipment being worn by the soldier. The operational levels of MOPP are described in the following:

MOPP0: no equipment worn, protective mask is carried
MOPP1: overgarment worn
MOPP2: overgarment, overboots worn
MOPP3: overgarment, overboots, protective mask with hood worn
MOPP4: total encapsulation with overgarment, overboots, protective mask with hood, and gloves

The mask only option exists if the soldier is protected from direct exposure to contamination. However, this option depends upon the type of contamination present even if protection in some form of shelter exists.

The protective equipment, while saving lives and reducing casualties, also presents a number of problems and can degrade performance. The problems encountered include a loss of manual dexterity, limited visual and hearing capability, fatigue and heat stress, restricted movement and psychological effects (FM 1-102, FM 3-100). The decrement in operational effectiveness has been estimated as high as 50% of the effectiveness without the equipment (Wagner & Gold, 1982). The performance decrement depends upon task complexity, the required MOPP level and the weather. As the level of MOPP increases, protection increases. However, operational effectiveness correspondingly decreases. Therefore, unit commanders have to carefully evaluate the situation in order to complete the mission while concurrently ordering the appropriate MOPP level for reducing casualties. The selection of MOPP level is based on such factors as "the threat, the mission to be accomplished, the vulnerability of friendly units to enemy attack, the weather, anticipated work rate, expected reaction time to a chemical attack, donning speed of protective equipment, and degradation impact of protective equipment" (FM 17-17, p. E-19).

Numerous research projects have investigated the impact of NBC protective equipment on performance (Muza, 1986). The conclusions of the research projects suggest a greater or lesser degree of performance decrements when soldiers are wearing NBC equipment. A research report examining the effects of wearing the M17 protective mask on combat (performance) tasks found less than

10% average loss due to the mask. The greatest degradation was found in voice communication with a decrement of 20% or more when compared to unmasked subjects (Montague, Baldwin, & McClure, 1959). A more recent investigation on the M17 protective mask also found decrements in verbal communication along with restricted vision (Barnes, Bruno, Hanlon, Harrah, Hickey, Merkey, Randall, & Shoemaker, 1983).

Visual limitations as a result of wearing the protective mask have been reported in several research projects (Cox & Jeffers, 1981; Muza, 1986). Degradation in vision when wearing the protective mask is a function of several factors including: (a) restrictions in the visual field of view, (b) reduced visual acuity, and (c) altered space and distance perception, (Muza, 1986). The visual field of view is restricted because the lens in the mask limits the amount of peripheral vision that would exist without the mask. Muza (1986) suggests that the decrements associated with the limitation in the visual field depends upon the specific task and conditions. ". . . tasks requiring a large visual field are degraded by mask wear whereas tasks utilizing a small visual field might not be affected" (Muza, 1986, p. 30).

Visual acuity has been examined by testing subjects on tracking a target at a constant rate across a visual field while the direction of the target varied randomly (Wiley, Behar, Chiow, & Holly, 1977). Wiley, et al. (1977) found that for those wearing a mask, the target angular size had to be increased up to 38% over the no-mask condition to achieve a 95% detection rate. The results of Wiley, et al. indicated that the mask interfered with the ability to detect and track a rapidly moving target. These results were extended by Kobrick and Sleeper (1986) when they measured response times to visual stimuli. The response times for detecting visual signals were significantly longer for those subjects wearing the mask in MOPP4. The results of these two projects suggest the protective mask can seriously impose visual limitations.

Previous research has indicated that the protective rubber gloves cause a substantial degradation in manual dexterity (Jauson & Jepson, 1982; Johnson & Sleeper, 1986). Manual dexterity includes: (a) fine motor response, (b) fine motor manipulation, and (c) fine motor strength (Ramirez, Shew, Felt, & Rayle, 1986). Johnson and Sleeper (1986) investigated the effects of wearing the mask, hood, and gloves in various combinations on one-handed and two-handed tests of manual dexterity. Their results indicated a substantial effect on performance for the protective gloves with or without wearing the mask. These results were also supported by Rauch, Witt, Banderet, Tauson, and Golden (1986). Their results revealed significant performance decrements on paper and pencil tests of math computation for those subjects wearing gloves. The mask had no significant effect by itself.

King and Frelin (1982) investigated the performance of medical specialists on nine medical tasks in fatigues and MOPP4. Their research focused on the effects of protective gloves on manual dexterity. Subjects in MOPP4 performed all the tasks significantly slower (30% to 55% on the average) than subjects in fatigues. However, King and Frelin (1982) did find substantial performance improvement over 6 days of practice when in MOPP4. These results indicate the substantial impact of the protective gloves on performance and yet the importance of regular training on tasks while in MOPP gear to reduce

the impact (Bensel, 1980). Several of the aforementioned research projects have found a significant effect for NBC equipment on speed or rate of task completion while no differences were found on accuracy (Fine & Kobrick, 1986; Kobrick & Sleeper, 1986; Rauch et al., 1986).

While soldier's performance in MOPP gear has been examined, relatively little data exist concerning the performance of Armor crewmen under NBC conditions. Existing research has focused on the physiological aspects of heat stress and fatigue resulting from the operational MOPP4 level with complete ensemble rather than performance variables such as the psychomotor tasks required in tank gunnery (Carr, Kershner, Corona, & Jackson, 1980). Performance degradation in tank crews has been examined in terms of stay time, the length of time in protective posture that a unit remains effective before experiencing casualties because of heat stress (Rakaczky, 1981). Work/rest cycles have been developed for crewmen under different MOPP levels depending upon temperature and humidity (FM 3-4).

Past research indicates the importance of assessing the effects of NBC protective equipment on Armor crewmen performance. Tank gunnery requires visual acuity, manual dexterity, and verbal communication for successful task performance. Because research already suggests performance decrements in these three areas, it seems imperative to determine the extent of degradation in gunnery performance. Performance decrements are also possible due to equipment failures resulting from battlefield conditions. Therefore, assessing deficiencies associated with MOPP gear and degraded operational conditions is warranted. Once the deficiencies have been determined, the amount of training required to counter the degradation can be ascertained.

Research Objectives

The Unit Conduct of Fire Trainer (UCOFT) is the most sophisticated simulator that is available for training tank commander/gunner pairs. Performance degradation resulting from the use of MOPP gear under various operational conditions can be simulated on the UCOFT. The objectives of this research project are:

(1) to quantify gunner performance on the UCOFT when wearing the protective mask and gloves under normal and emergency operational mode and

(2) to suggest training countermeasures to alleviate possible performance deficiencies.

The research was designed to assess the effects of the protective mask and gloves on vision and manual dexterity. The operational MOPP4 level which includes the mask and gloves was not simulated. The overgarment, overboots, and hood required at the MOPP4 level were not used in order to control for possible heat stress and fatigue. Therefore, the results for MOPP gear in this research are only based on the effects of mask and gloves and cannot be generalized to the actual operational MOPP4 level.

EXPERIMENT I

Method

Subjects

The subjects were 48 M1 qualified gunners from the M1 New Equipment Training Team (NETT) at the U.S. Army Armor Center (USAARMC) at Fort Knox. Four M1 qualified tank commanders (TCs) from the M1 NETT Team assisted in testing gunner performance by serving as tank commanders.

Apparatus

The M1 Unit Conduct of Fire Trainer (UCOFT) was used as the medium for measuring gunner performance. The UCOFT is a high fidelity gunnery trainer which employs computer-generated target scenarios and a realistic crew compartment. The majority of controls and switches used by the gunner and TC in the M1 tank are simulated in the UCOFT. Target exercises on the UCOFT sample numerous engagement conditions such as weather and visibility conditions, tactical situations, and equipment operational readiness. The Instructor/Operator (I/O) controls the trainer from an external station. The I/O's station is equipped with visual displays of the tank commander and gunner's sights. The information displayed includes target type, reticle used, operational status and the running time for target appearance with the direction and magnitude in degrees of the target from the reticle. The I/O can observe what the TC/gunner pair view through their sights and can monitor and control their progress through the exercises. A computer print-out details performance during each engagement within each exercise by recording measures such as number of target hits, number of rounds fired, and target identification time.

To simulate Nuclear, Biological, and Chemical (NBC) conditions in the present experiment, the M25/M25A1 tank protective mask and the chemical-protective glove set were used as the Mission Oriented Protective Posture (MOPP) gear. The hood, overgarment, and overboots were not used in the project to preclude the possible physiological effects of heat stress and fatigue.

UCOFT Exercises

All exercises employed in the present experiment included single target engagements with day unlimited visibility. The targets were either T72 tanks, helicopters, personnel carriers, or trucks. Only main gun engagements were used. The gunner could fire only one round of ammunition per target engagement. The gunner had 20 seconds after full target exposure to kill the target before the engagement was terminated by the computer. In stationary own tank engagements, the engagement began in a defensive posture (turret down position). The gunner's tank could be exposed (hull down position) for only 15 seconds before the computer simulated its destruction. (See Appendix A for listing of specific exercises.)

Procedure

Preliminary training. The I/Os and TCs were specifically trained on all exercises used in the experiment to standardize procedures in the pretest and experimental conditions. The TCs were trained to issue the appropriate fire command corresponding to each engagement using doctrinally correct M1 conduct of fire procedures. This procedure standardized the fire commands for each subject. The TCs were also trained to lay the reticle on a predetermined landmark (i.e., house, rock, tree, etc.) for each engagement before target presentation. This was done to ensure the same starting point for all subjects in each engagement. This procedure increased the standardization of target acquisition time measures (see Smith & Graham, 1987). The landmarks were approximately five mils either left or right of the potential target appearance. The targets were within the gunner's 3X sight picture when they appeared. Additionally, the I/Os were trained in the following duties:

(1) to identify the exercise to the TC and gunner.

(2) to give instructions explaining the exercise to the subject.

(3) to direct the TC to the landmark before target appearance.

(4) to punch in the gunner's target identification response.

(5) to act as the driver by moving the tank in and out of defilade during stationary own tank engagements.

(6) to act as the driver by stopping and starting the tank during moving own tank engagements in emergency mode.

(7) to print out all performance measures and call up the next exercise.

Group assignment. Subjects were randomly assigned to one of four experimental conditions defined by level of MOPP and operational mode. The four experimental groups were: (a) Group 1: No MOPP, normal operational mode, (b) Group 2: Mask only, normal operational mode, (c) Group 3: Mask and gloves, normal operational mode, and (d) Group 4: Mask and gloves, emergency operational mode (see Table 1).

Instructions-Pretest. Subjects were read instructions explaining the nature of the testing procedures and the UCOFT (see Appendix B). The range of experience on the UCOFT was considerable (see Appendix C for biographical summary data). Therefore, initial performance was measured for possible inclusion as a covariate in the analyses. A pretest was used which consisted of 20 engagements representing the different types of exercises used in the experimental conditions. Subjects were not in MOPP gear for the pretest and performed under normal operational mode. Subjects were allowed to ask any questions about the UCOFT or the experimental procedures during this pretest period. They were told that no questions would be answered or assistance provided by the I/O or TC during the experimental conditions. Subjects were then given a 10 minute break during which time they completed a biographical questionnaire (see Appendix D).

Table 1

Experimental Conditions for Groups in Experiment I

MOPP Gear	Operational Mode	
	Normal	Emergency
No MOPP	Group 1	
Mask	Group 2	
Mask and Gloves	Group 3	Group 4

Experimental conditions. After the break, those subjects in the groups requiring MOPP gear donned the appropriate equipment and proceeded with the test exercises. TCs were not in MOPP gear. All subjects completed six test exercises on the UCOFT in two sessions of three exercises each. The two sessions were separated by a ten minute break to control for the effects of fatigue. The six test exercises were counterbalanced within each group. The six exercises were the following:

(1) stationary own tank, long range stationary targets.

(2) moving own tank, short range stationary targets.

(3) moving own tank, long range stationary targets.

(4) stationary own tank, short range moving targets.

(5) stationary own tank, long range moving targets.

(6) moving own tank, short range moving targets

For Groups 1, 2 and 3, the exercises required precision gunnery using the gunner's primary sight (GPS). For Group 4, the conditions were degraded to an emergency mode. Subjects were informed that the computer, laser range finder, stabilization system, and the GPS were nonfunctional prior to commencing the exercises. Switches on the UCOFT were used to change operational readiness. The switch configuration was an alternative to employing UCOFT exercises specifically designed to simulate the degraded conditions. By using the switches on the UCOFT, the exercises then remained identical to the other three groups except for operational mode. The Mode switch was placed in Off; the Range switch was placed in Safe; the Thermal Mode switch was in the Off position; and the Filter/Clear/Shutter switch was placed in Shutter. With the GPS nonfunctional, the TC had to use the 50 Caliber sight for making the initial lay on the landmark. In Group 4, under emergency operational

mode, short range engagements required Battlesight techniques. For long range targets, the actual target range was included in the fire command. The gunner had to use the gunner's auxiliary sight (GAS) to apply manual lead to moving targets. For moving own tank exercises, the gunner had to engage the target from a short halt.

Performance Measures

Performance measures of fire time, percent hits and aiming error were used in both the pretest and the experimental conditions. Measures extracted from the UCOFT print-outs included: (a) average fire time, the elapsed time in seconds from full target exposure to when the gunner fires, (b) number of target hits, (c) number of targets presented, (d) average azimuth error in mils, and (e) average elevation error in mils. The rounds of ammunition generated in the UCOFT have a greater or lesser degree of dispersion. A target hit that results from a dispersion round may or may not be an actual hit. Therefore, this type of engagement was deleted from all exercises. A miss that results from a dispersion round that would have been a hit otherwise was counted as a hit.

Percent hits was computed as a measure of accuracy for each exercise from the number of hits and number of target presentations. Aiming error was computed and equaled the root mean square (RMS) of azimuth and elevation error (Smith & Graham, 1987), RMS = $\sqrt{\text{azimuth error}^2 + \text{elevation error}^2}$. Aiming error is an index of the distance in mils from the reticle to the center of target mass at time of round impact.

Biographical Measures

All subjects completed a biographical questionnaire. The biographical measures were: (a) total time in the military, (b) total time in Armor, (c) total time as a gunner, (d) self-reported General Technical (GT) score from the Armed Services Vocational Aptitude Battery (ASVAB), and (e) number of hours of experience on the UCOFT. Time in military, time in Armor, time as a gunner, and hours on the UCOFT were used as measures of experience. The GT score was considered a measure of aptitude.

Experimental Design

The experimental design was a 4 x 6 repeated measures design with four groups and six different exercises. Multivariate analysis of variance on repeated measures was used with post hoc comparisons on all significant main effects and interactions. Pearson correlations were obtained between performance measures and the biographical variables. Average performance measures across exercises in the experimental conditions were used in the correlational analyses. Multiple correlations between performance measures and biographical variables were obtained from multiple regression analyses using a hierarchical forced entry procedure (Cohen & Cohen, 1983). The experience measures of time in military, time in Armor, time as gunner, and hours on UCOFT were entered into the regression equation as a functional set of

variables. Because the sample included subjects with a great amount of experience, experience was hypothesized as having a larger effect on performance than GT score. Thus, the set of experience variables was always entered first into the equation and the GT score was entered last.

Results

Subjects were randomly assigned to one of four experimental groups:

(1) Group 1: No MOPP, normal operational mode.

(2) Group 2: Mask only, normal operational mode.

(3) Group 3: Mask and gloves, normal operational mode.

(4) Group 4: Mask and gloves, emergency operational mode.

All groups received a pretest consisting of representative exercises from the experimental conditions. The pretest was identical for all subjects. Subjects were not in MOPP gear for the pretest and performed under normal operational mode conditions. After the pretest, subjects performed six different exercises under the experimental conditions according to assigned group. Performance measures of fire time, percent hits, and aiming error were used in both the pretest and in the experimental conditions.

Pretest Performance

A one-way multivariate analysis of variance (MANOVA) was performed on pretest performance measures to assess possible group differences in initial performance (see Appendix E for summary data on pretest performance). A significant group effect was found for aiming error ($F(3,44)=3.99$; $p=0.13$). Fire time, percent hits, and aiming error were intercorrelated (see Appendix F). Therefore, all three pretest performance measures were subsequently used as covariates in the analyses of experimental test performance.

Experimental Test Performance

Multivariate analysis of variance (MANOVA) on repeated measures with constant covariates was used to determine if significant group differences existed on experimental test performance (see Table 2 for summary data). (See Appendix G for complete summary data on performance measures by exercise.) MANOVA summary tables present complete results of the analyses (see Tables 3, 4, and 5). As detailed in the MANOVA tables, the overall group main effect was significant for each performance measure. Results of the post hoc comparisons between groups indicated a significant difference for Group 4 (Mask and gloves, emergency mode) on each measure. The only significant difference for the groups in MOPP gear under normal operational mode (Group 2 and Group 3) was on aiming error (see Table 5).

Table 2

Summary Data on Experimental Test Performance by Group for Experiment I

Group[a]		Average Fire Time	Average Percent Hits	Average Aiming Error
1.	No MOPP Normal Operational Mode			
	M	13.33	78.94	1.17
	SD	1.84	9.42	0.24
2.	Mask Only Normal Operational Mode			
	M	14.46	79.66	1.27
	SD	2.06	4.41	0.29
3.	Mask and Gloves Normal Operational Mode			
	M	13.58	80.51	1.23
	SD	1.96	3.83	0.22
4.	Mask and Gloves Emergency Operational Mode			
	M	15.37	65.01	1.56
	SD	1.69	8.56	0.26

Note. Fire time is the elapsed time (seconds) from full target exposure to when the gunner fires. Percent hits = (number of hits/number of targets presented) x 100. Aiming error (mils) = square root [(azimuth error)^2 + (elevation error)^2].

[a] n = 12 per group.

The MANOVA tables indicate a significant exercise main effect for each performance measure. Post hoc comparisons between exercises revealed a significant effect for long range targets on fire time and percent hits in all groups with lower performance in long range target exercises compared to short range target exercises for both variables (see Tables 3 and 4). The comparisons also indicated significantly lower performance on each measure in the stationary own tank/moving target exercise compared to the moving own tank/stationary target exercise. The interaction between target range and the stationary own tank/moving target exercise and moving own tank/stationary target exercise was significant for all measures. Summary data for the individual exercises indicate for fire time, range had a more substantial effect in the moving own tank/stationary target exercise versus the stationary own tank/moving target exercise. On the other hand, for percent hits and aiming error, the reverse was true. Range had a greater effect in the stationary own tank/moving target exercise versus the moving own tank/stationary target exercise.

Table 3

MANOVA Summary Table for Fire Time on Experiment I

Source (Adjusted)	df	F	p level
MAIN EFFECTS:			
Group	3,43	10.20	.000
Exercise	5,40	67.46	.000
INTERACTION:			
Group x Exercise	15,110.82	2.45	.004
POST HOC COMPARISONS:			
Group			
Group 4 versus Group 1, 2, 3	1,43	25.33	.000
Group 2, 3 versus Group 1	1,43	0.82	ns
Target Range			
Exercise 1, 3, 5 versus Exercise 2, 4, 6	1,44	193.69	.000
Stationary Tank/Moving Target - Moving Tank/Stationary Target			
Exercise 4, 5 versus Exercise 2, 3	1,44	115.84	.000
Target Range x Stationary Tank/Moving Target-Moving Tank/Stationary Target	1,44	30.60	.000
Group 4 versus Group 1, 2, 3 x Exercise	5,40	4.62	.002
Group 2, 3 versus Group 1 x Exercise	5,40	1.85	ns
Group 4 versus Group 1, 2, 3 x Target Range	1,44	18.35	.000
Group 4 versus Group 1, 2, 3 x Stationary Tank/Moving Target-Moving Tank/Stationary Target	1,44	0.08	ns

Table 4

MANOVA Summary Table for Percent Hits on Experiment I

Source (Adjusted)	df	F	p level
MAIN EFFECTS:			
Group	3,43	15.39	.000
Exercise	5,40	51.36	.000
INTERACTION:			
Group x Exercise	15,110.82	2.68	.002
POST HOC COMPARISONS:			
Group			
Group 4 versus Group 1, 2, 3	1,43	44.96	.000
Group 2, 3 versus Group 1	1,43	0.09	ns
Target Range			
Exercise 1, 3, 5 versus Exercise 2, 4, 6	1,44	38.47	.000
Stationary Tank/Moving Target - Moving Tank/Stationary Target			
Exercise 4, 5 versus Exercise 2, 3	1,44	88.50	.000
Target Range x Stationary Tank/Moving Target-Moving Tank/Stationary Target	1,44	12.33	.001
Group 4 versus Group 1, 2, 3 x Exercise	5,40	8.01	.000
Group 2, 3 versus Group 1 x Exercise	5,40	0.15	ns
Group 4 versus Group 1, 2, 3 x Target Range	1,44	0.15	ns
Group 4 versus Group 1, 2, 3 x Stationary Tank/Moving Target-Moving Tank/Stationary Target	1,44	41.69	.000

Table 5

MANOVA Summary Table for Aiming Error on Experiment I

Source (Adjusted)	df	F	p level
MAIN EFFECTS:			
Group	3,43	9.08	.000
Exercise	5,40	71.53	.000
INTERACTION:			
Group x Exercise	15,110.82	2.73	.001
POST HOC COMPARISONS:			
Group			
Group 4 versus Group 1, 2, 3	1,43	23.44	.000
Group 2, 3 versus Group 1	1,43	3.96	.053
Target Range			
Exercise 1, 3, 5 versus Exercise 2, 4, 6	1,44	0.26	ns
Stationary Tank/Moving Target - Moving Tank/Stationary Target			
Exercise 4, 5 versus Exercise 2, 3	1,44	69.53	.000
Target Range x Stationary Tank/Moving Target-Moving Tank/Stationary Target	1,44	4.21	.046
Group 4 versus Group 1, 2, 3 x Exercise	5,40	9.41	.000
Group 2, 3 versus Group 1 x Exercise	5,40	0.27	ns
Group 4 versus Group 1, 2, 3 x Target Range	1,44	9.37	.004
Group 4 versus Group 1, 2, 3 x Stationary Tank/Moving Target-Moving Tank/Stationary Target	1,44	44.29	.000

A significant interaction between group and exercise was found for each measure as illustrated in the MANOVA tables. The post hoc comparisons revealed a significant interaction between Group 4 and exercise on each measure. No significant interactions were found between the MOPP groups (Group 2 and Group 3) and exercise. Group 4 had a significantly slower fire time in long range target exercises with no difference for Group 4 in the short range target exercises (see Table 3). A significant difference existed for Group 4 on percent hits in the stationary own tank/moving target exercise with no difference in the moving own tank/stationary target exercise (see Table 4). For aiming error, significant effects existed for Group 4 on long range target exercises and the stationary own tank/moving target exercise (see Table 5).

Pearson Correlations and Multiple Regression

The relationship among performance measures and the biographical variables were examined using Pearson product moment correlations. Results suggest a stronger relationship between biographical variables and fire time than with the other performance measures. Seven of the ten correlations between fire time and the biographical variables were significant. Only two of the ten correlations between percent hits and the biographical variables were significant and four of ten correlations between aiming error and biographical variables were significant (see Table 6).

Multiple correlations between performance measures on the pretest and in the experimental conditions and measures of experience and GT score were examined by multiple regression. A hierarchical forced entry procedure was used in the multiple regression analyses (Cohen & Cohen, 1983). The experience measure of time in military, time in Armor, time as gunner, and hours on UCOFT were entered into the regression equation as a functional set of variables (see Appendix H for intercorrelations between biographical variables). Because the sample included subjects with a great amount of experience, experience was hypothesized as having a larger effect on performance than the GT score. Thus, the set of experience variables was always entered first into the equation. The GT score was entered last. If the overall F statistic for the set was significant, the Beta weights of constituent variables in the regression equation were examined separately.

The multiple correlation between fire time on the pretest and the functional set of experience variables was significant, ($R=.59$, $R^2=.35$, $F(4,42)=5.71$; $p=.001$). Two variables were significantly weighted in the regression equation: time as gunner ($t[42]=-2.11$, $p=.041$) and hours on UCOFT ($t[42]=-2.60$; $p=.013$). The negative sign of the t values correspond to the negative Beta weights which are in the expected direction. The GT score was not significantly weighted in the regression equation. The multiple correlation between average fire time in the experimental conditions and the set of experience variables was also significant, ($R=.52$, $R^2=.27$, $F(4,42)=3.90$; $p=.009$). The only significantly weighted constituent variable in the equation was time as gunner, ($t[42]=-2.59$; $p=.013$), with the negative Beta weight again in the expected direction. The GT score was not significantly weighted in the equation.

Table 6

Pearson Correlations between Performance Measures on the Pretest and in the Experimental Conditions and Biographical Variables for Experiment I

	Time in Military	Time in Armor	Time as Gunner	GT Score	Hours on UCOFT
Pretest Fire Time	.4022 (48) p=.002	.3860 (48) p=.003	-.3129 (48) p=.015	.2280 (47) p=.062	-.3483 (48) p=.008
Pretest Percent Hits	-.1828 (48) p=.107	-.2483 (48) p=.044	.1421 (48) p=.168	.1324 (47) p=.188	.2478 (48) p=.045
Pretest Aiming Error	.1668 (48) p=.129	.1358 (48) p=.179	-.1645 (48) p=.132	-.2388 (47) p=.053	-.1674 (48) p=.128
Experiment Fire Time	.3460 (48) p=.008	.2383 (48) p=.051	-.4092 (48) p=.002	-.0183 (47) p=.451	-.2013 (48) p=.085
Experiment Percent Hits	-.0379 (48) p=.399	.1141 (48) p=.220	.2291 (48) p=.059	.1082 (47) p=.235	.0880 (48) p=.276
Experiment Aiming Error	-.1383 (48) p=.174	-.2739 (48) p=.030	-.3011 (48) p=.019	-.2644 (47) p=.036	.0352 (48) p=.406

There were no significant multiple correlations between percent hits in the pretest or experimental conditions and the biographical variables. There was no significant multiple correlation between pretest aiming error and the biographical variables. However, the multiple correlation between average aiming error in the experimental conditions and the set of experience variables was significant, ($R=.46$, $R^2=.21$, $F(4,42)=2.79$; $p=.038$). The only significantly weighted constituent variable in the regression equation was again time as gunner, ($t[42]=-2.43$; $p=.019$) with a negative Beta weight in the expected direction. (See Table 7 for details of the multiple regression analyses).

Table 7

Results of Multiple Regression Analyses of Performance Measures by the Biographical Variables for Experiment I

	Multiple R	R^2	R^2 Change	F	df	p level	Beta	t	p level
Pretest Fire Time									
Set of Experience Variables	.59	.35	.35	5.71	4,42	.001			
GT Score	.63	.39	.04	2.59	5,41	ns			
Variables in the Equation:									
Time in Military							.049	0.22	ns
Time in Armor							.315	1.43	ns
Time as Gunner							-.266	-2.11	.041
Hours on UCOFT							-.326	-2.60	.013
GT Score							.198	1.61	ns
Overall Model				5.26	5,41	.001			
Experiment Fire Time									
Set of Experience Variables	.52	.27	.27	3.90	4,42	.009			
GT Score	.52	.27	.00	0.04	5,41	ns			
Variables in the Equation:									
Time in Military							.262	1.06	ns
Time in Armor							-.009	-0.39	ns
Time as Gunner							-.356	-2.59	.013
Hours on UCOFT							-.168	-1.23	ns
GT Score							-.028	-0.21	ns
Overall Model				3.06	5,41	.019			

Note. p levels > .10 = not significant (ns)

Table 7 (Continued)

Results of Multiple Regression Analyses of Performance Measures by the Biographical Variables for Experiment I

	Multiple R	R^2	R^2 Change	F	df	p level	Beta	t	p level
Pretest Percent Hits									
Set of Experience Variables	.40	.16	.16	1.99	4,42	ns			
GT Score	.43	.19	.03	1.42	5,41	ns			
Variables in the Equation:									
Time in Military							.234	0.89	ns
Time in Armor							-.407	-1.60	ns
Time as Gunner							.129	0.89	ns
Hours on UCOFT							.321	2.22	.032
GT Score							.169	1.19	ns
Overall Model				1.89	5,41	ns			
Experiment Percent Hits									
Set of Experience Variables	.33	.11	.11	1.29	4,42	ns			
GT Score	.35	.12	.01	0.58	5,41	ns			
Variables in the Equation:									
Time in Military							-.308	-1.14	ns
Time in Armor							.381	1.44	ns
Time as Gunner							.208	1.37	ns
Hours on UCOFT							.053	0.35	ns
GT Score							.113	0.76	ns
Overall Model				1.14	5,41	ns			

Note. p levels > .10 = not significant (ns)

Table 7 (Continued)

Results of Multiple Regression Analyses of Performance Measures by the Biographical Variables for Experiment I

	Multiple R	R^2	R^2 Change	F	df	p level	Beta	t	p level
Pretest Aiming Error									
Set of Experience Variables	.27	.07	.07	0.85	4,42	ns			
GT Score	.38	.14	.07	3.27	5,41	.078			
Variables in the Equation:									
Time in Military							.038	0.14	ns
Time in Armor							.071	0.27	ns
Time as Gunner							-.124	-0.83	ns
Hours on UCOFT							-.226	-1.52	ns
GT Score							-.264	-1.81	.078
Overall Model				1.37	5,41	ns			
Experiment Aiming Error									
Set of Experience Variables	.46	.21	.21	2.79	4,42	.038			
GT Score	.52	.28	.07	3.68	5,41	.062			
Variables in the Equation:									
Time in Military							.153	0.62	ns
Time in Armor							-.415	-1.73	.092
Time as Gunner							-.333	-2.43	.019
Hours on UCOFT							.063	0.46	ns
GT Score							-.258	-1.92	.062
Overall Model				3.11	5,41	.018			

Note. p levels > .10 = not significant (ns)

Discussion

The purpose of Experiment I was to examine the effects of MOPP gear and operational mode on gunner performance. Aiming error was significantly larger for the groups in MOPP gear, but no significant effects for MOPP gear were found for fire time and percent hits under normal operational mode conditions. Overall, the results suggest that wearing MOPP gear in a fully operational tank does not necessarily lead to large performance decrements in gunner performance. However, when equipment failures force emergency operational mode conditions, in addition to MOPP gear, a significant performance drop occurs.

The results also indicate that the level of gunner performance decrement when wearing MOPP gear under emergency mode conditions may depend upon the type of target engagement. For example, MOPP gear and emergency mode significantly degraded fire time and aiming error in long range target engagements, but did not affect performance in short range target engagements. Also, in the stationary own tank and moving target exercise, percent hits and aiming error were significantly affected by MOPP gear and emergency mode, while no differences existed when the tank was moving and the targets were stationary. However, in emergency mode conditions when the stabilization system is nonfunctional, the gunner must wait for the tank to halt before firing. This factor caused the moving own tank/stationary target exercise to become a stationary own tank/stationary target exercise for Group 4. In sum, the results suggest that the effects of degradation on gunner performance may depend upon situational determinants and performance decrements cannot be assumed for all target engagements.

The multiple regression analyses revealed a significant multiple correlation between gunner fire time and the set of experience variables, particularly overall time as gunner. The negative Beta weight in the regression equation corresponding to time as gunner was in the expected direction. This result was also found for aiming error in the experimental conditions. These results suggest that when time as gunner increases, fire time decreases, hence, the faster the gunner's speed at firing a round of ammunition, and also the gunner's aiming error decreases. Therefore, the level of gunner experience may greatly affect certain performance measures under degraded operational conditions.

The present experiment suggest significant effects of MOPP gear and emergency mode conditions on gunner performance when they occur simultaneously. The present experiment, however, did not examine the interaction of MOPP gear and operational mode. Level of performance degradation may be greater when combining MOPP gear and emergency mode conditions than when either factor occurs alone. The interaction between MOPP gear and operational mode is thus examined in Experiment II.

EXPERIMENT II

Method

In Experiment I, the combination of MOPP gear and emergency operational mode conditions significantly impaired gunnery performance. In order to assess the interaction between MOPP gear and operational mode, another sample of subjects was formed. Data from a group of subjects which performed exercises under emergency operational mode on the UCOFT under the same switch configurations but without MOPP gear were available from another project (Witmer, in progress). The subjects were also M1 qualified gunners from the M1 NETT Team, but were not subjects in Experiment I. A 2 x 2 experimental design was thus formed. The experimental groups were: (a) Group 1: No MOPP, normal operational mode (from Experiment 1), (b) Group 2: No MOPP, emergency operational mode (from Witmer's project), (c) Group 3: MOPP (mask and gloves), normal operational mode (from Experiment I), and (d) Group 4: MOPP (mask and gloves), emergency operational mode (from Experiment I) (see Table 8).

Table 8

Experimental Conditions for Groups in Experiment II

MOPP Gear	Operational Mode	
	Normal	Emergency
No MOPP	Group 1	Group 2
Mask and Gloves	Group 3	Group 4

The testing procedures for both projects were identical which included the duties of the I/Os and TCs, the pretest for beginning performance, and six test exercises. The single discrepancy between the two projects occurred in the test exercises. Only four of the six exercises were the same in both projects. Therefore, only those four exercises which were the same were included in the data analyses. The other two exercises were omitted from the experiment. The four exercises were:

(1) moving own tank, short range moving targets.

(2) stationary own tank, long range stationary targets.

(3) stationary own tank, short range moving targets.

(4) stationary own tank, long range moving targets.

All exercises were single tank engagements with day unlimited visibility. Only main gun engagements were used and the gunner could fire only one round of ammunition per target engagement (see Appendix I for listing of specific exercises). See Method section in Experiment I for further details of testing procedures and explanation of exercises and conditions. The performance measures and biographical measures remained the same as in Experiment I.

Experimental Design

The experimental design was a 2 x 2 x 4 repeated measures design with two levels of MOPP gear, two levels of operational mode, and four exercises. Multivariate analysis of variance on repeated measures was used with post hoc comparisons on all significant main effects and interactions. Pearson correlations were obtained between performance measures and the biographical variables. Average performance measures across exercises in the experimental conditions were used in the correlational analyses. Multiple correlations between performance measures and the biographical variables were obtained from multiple regression analyses using a hierarchical forced entry procedure (Cohen & Cohen, 1983). The experience measures of time in military, time in Armor, time as gunner, and hours on UCOFT were entered into the regression equation as a functional set of variables. Because the sample included subjects with a great amount of experience, experience was hypothesized as having a larger effect on performance than GT score. Thus, the set of experience variables was always entered first into the equation and the GT score was entered last.

Results

Three groups from Experiment I were combined with a group of subjects from another project to form a two by two experimental design consisting of the following groups:

(1) Group 1: No MOPP, normal operational mode.

(2) Group 2: No MOPP, emergency operational mode.

(3) Group 3: MOPP (mask and gloves), normal operational mode.

(4) Group 4: MOPP (mask and gloves), emergency operational mode.

All groups received a pretest consisting of representative exercises from the experimental conditions. Subjects were not in MOPP gear for the pretest and performed under normal operational mode conditions. Four test exercises were performed under the experimental conditions according to assigned group. Performance measures of fire time, percent hits, and aiming error were used in both the pretest and in the experimental conditions.

Pretest Performance

A one-way multivariate analysis of variance (MANOVA) was performed on pretest performance measures to assess group differences in beginning performance (see Appendix J for summary data). No significant group differences were found on any measure. Therefore, no covariates were used in the analyses on experimental test performance. (See Appendix K for intercorrelations between performance measures on the pretest and in the experimental conditions.)

Experimental Test Performance

Multivariate analysis of variance (MANOVA) on repeated measures was performed on each measure from the experimental conditions (see Table 9 for summary data). (See Appendix L for complete summary data on performance measures by exercise.) Post hoc comparisons were performed on significant main effects and interactions. Planned comparisons were used to examine the differences between short and long range targets in the stationary own tank/moving target exercise. Differences between stationary and moving targets were examined in the stationary own tank/long range stationary target exercise versus the stationary own tank/long range moving target exercise. Finally, the differences between stationary own tank and moving own tank were examined in the moving own tank/short range moving target exercise versus the stationary own tank/short range moving target exercise. MANOVA summary tables present complete results of the analyses.

As detailed in the MANOVA tables, the overall main effect for operational mode was significant for each performance measure, (see Tables 10, 11 and 12). Emergency mode significantly degraded fire time, percent hits, and aiming error. There was no significant effect for MOPP gear on any performance measure nor were there any significant interactions between MOPP gear and operational mode. The MANOVA tables indicate a significant exercise main effect for each measure. Planned comparisons between exercises on target range indicated a significant effect for long range targets on each performance measure. The comparisons also indicated a significant effect for moving targets on percent hits and aiming error. A significantly higher fire time existed in the stationary own tank exercise and a significantly higher aiming error in the moving own tank exercise.

The interaction between MOPP and exercise was not significant for any measure as illustrated in the MANOVA tables. The interaction between operational mode and exercise was significant for fire time and aiming error (see Tables 10 and 12). Post hoc comparisons indicated a significantly slower fire time in the long range target exercises under emergency mode conditions. No significant differences existed between modes for fire time in the short range target exercises. Fire time was significantly longer in the moving target exercise under normal mode conditions, however, no difference existed between the stationary and moving target exercise under emergency mode. Fire time was significantly longer in both the stationary and moving target exercises under emergency mode conditions.

Table 9

Summary Data on Experimental Test Performance by Group for Experiment II

Group[a]	Average Fire Time	Average Percent Hits	Average Aiming Error
1. No MOPP Normal Operational Mode			
M	14.20	77.91	1.28
SD	1.74	9.30	0.26
2. No MOPP Emergency Operational Mode			
M	16.09	50.08	1.95
SD	1.15	8.90	0.33
3. Mask and Gloves Normal Operational Mode			
M	14.43	78.72	1.31
SD	1.97	10.26	0.26
4. Mask and Gloves Emergency Operational Mode			
M	16.32	53.64	1.93
SD	1.93	10.37	0.35

Note. Fire time is the elapsed time (seconds) from full target exposure to when the gunner fires.
Percent hits = (number of hits/number of targets presented) x 100.
Aiming error (mils) = square root [(azimuth error)^2 + (elevation error)^2].

[a] n = 12 per group.

Table 10

MANOVA Summary Table for Fire Time on Experiment II

Source	df	F	p level
MAIN EFFECTS:			
MOPP (Mask and Gloves)	1,44	0.21	ns
Operational Mode	1,44	14.26	.000
Exercise	3,42	70.47	.000
INTERACTION:			
MOPP x Operational Mode	1,44	0.00	ns
MOPP x Exercise	3,42	2.32	ns
Operational Mode x Exercise	3,42	15.16	.000
MOPP x Operational Mode x Exercise	3,42	0.58	ns
PLANNED COMPARISONS:			
Target Range			
Exercise 3 versus Exercise 4	1,44	48.85	.000
Stationary/Moving Target			
Exercise 2 versus Exercise 4	1,44	2.37	ns
Stationary Tank/Moving Tank			
Exercise 3 versus Exercise 1	1,44	63.67	.000
POST HOC COMPARISONS:			
Operational Mode x Target Range	1,44	8.05	.007
Normal Mode x Target Range	1,44	8.62	.005
Emergency Mode x Target Range	1,44	48.27	.000
Operational Mode x Short Range Target	1,44	0.52	ns
Operational Mode x Long Range Target	1,44	8.38	.006
Operational Mode x Stationary/Moving Target	1,44	10.57	.002
Normal Mode x Stationary/Moving Target	1,44	11.47	.001
Emergency Mode x Stationary/Moving Target	1,44	1.46	ns
Operational Mode x Stationary Target	1,44	38.99	.000
Operational Mode x Moving Target	1,44	8.38	.006
Operational Mode x Stationary/Moving Tank	1,44	3,67	ns

Table 11

MANOVA Summary Table for Percent Hits on Experiment II

Source	df	F	p level
MAIN EFFECTS:			
MOPP (Mask and Gloves)	1,44	0.61	ns
Operational Mode	1,44	88.68	.000
Exercise	3,42	76.79	.000
INTERACTION:			
MOPP x Operational Mode	1,44	0.24	ns
MOPP x Exercise	3,42	1.11	ns
Operational Mode x Exercise	3,42	2.25	ns
MOPP x Operational Mode x Exercise	3,42	1.39	ns
PLANNED COMPARISONS:			
Target Range			
Exercise 3 versus Exercise 4	1,44	111.51	.000
Stationary/Moving Target			
Exercise 2 versus Exercise 4	1,44	174.68	.000
Stationary Tank/Moving Tank			
Exercise 3 versus Exercise 1	1,44	2.85	ns

Table 12

MANOVA Summary Table for Aiming Error on Experiment II

Source	df	F	p level
MAIN EFFECTS:			
MOPP (Mask and Gloves)	1,44	0.00	ns
Operational Mode	1,44	53.42	.000
Exercise	3,42	127.59	.000
INTERACTION:			
MOPP x Operational Mode	1,44	0.10	ns
MOPP x Exercise	3,42	2.65	ns
Operational Mode x Exercise	3,42	19.07	.000
MOPP x Operational Mode x Exercise	3,42	0.82	ns
PLANNED COMPARISONS:			
Target Range			
Exercise 3 versus Exercise 4	1,44	41.79	.000
Stationary/Moving Target			
Exercise 2 versus Exercise 4	1,44	228.26	.000
Stationary Tank/Moving Tank			
Exercise 3 versus Exercise 1	1,44	4.84	.033
POST HOC COMPARISONS:			
Operational Mode x Target Range	1,44	19.12	.000
Normal Mode x Target Range	1,44	2.19	ns
Emergency Mode x Target Range	1,44	58.72	.000
Operational Mode x Short Range Target	1,44	8.54	.005
Operational Mode x Long Range Target	1,44	54.92	.000
Operational Mode x Stationary/Moving Target	1,44	48.83	.000
Normal Mode x Stationary/Moving Target	1,44	11.47	.001
Emergency Mode x Stationary/Moving Target	1,44	1.46	ns
Operational Mode x Stationary Target	1,44	1.72	ns
Operational Mode x Moving Target	1,44	54.92	.000
Operational Mode x Stationary/Moving Tank	1,44	5.85	.020
Normal Mode x Stationary/Moving Tank	1,44	10.67	.002
Emergency Mode x Stationary/Moving Tank	1,44	0.02	ns
Operational Mode x Stationary Tank	1,44	8.54	.005
Operational Mode x Moving Tank	1,44	0.03	ns

As Table 12 indicates, post hoc comparisons revealed no significant difference for aiming error between the short range and the long range target exercises in normal mode conditions. However, a significant difference existed for aiming error between the short range and long range target exercises in emergency mode. A significantly higher aiming error occurred under emergency mode conditions in the moving target exercise, but no difference existed between operational modes in the stationary target exercise. A significantly lower aiming error occurred in the stationary own tank exercise versus the moving own tank for those groups under normal operational mode. No difference existed between the exercises for groups in emergency mode.

Pearson Correlations and Multiple Regression

The relationship among performance measures and the biographical variables were examined using Pearson product moment correlations (see Appendix M for biographical summary data). Results again suggest a stronger relationship between biographical variables and fire time than with the other performance measures. Five of the ten correlations between fire time and the biographical variables were significant. Only one of the ten correlations between percent hits and the biographical variables was significant. Furthermore, only one of the ten correlations with aiming error was significant (see Table 13).

Multiple correlations between the measures of performance on the pretest and in the experimental conditions and the measures of experience and GT score were examined by multiple regression. A hierarchical forced entry procedure was used in the multiple regression analyses (Cohen & Cohen, 1983). The experience measures of time in military, time in Armor, time as gunner, and hours on UCOFT were entered into the regression equation as a functional set of variables (see Appendix N for intercorrelations between biographical variables). Because the sample included subjects with a great amount of experience, experience was hypothesized as having a larger effect on performance than the GT score. Thus, the set of experience variables was always entered first into the equation and the GT score was entered last. If the overall F statistic for the set was significant, the Beta weights of constituent variables in the regression equation were examined separately.

The multiple correlation between fire time on the pretest and the functional set of experience variables was significant, ($R=.63$, $R^2=.40$, $F(4,42)=6.91$; $p=.000$). The two variables which significantly weighted in the regression equation were: time as gunner ($t[42]=-2.14$; $p=.038$) and time in military ($t[42]=2.05$; $p=.047$). The negative sign of the t value corresponding to the negative Beta weight for time as gunner was in the expected direction. However, the Beta weight for time in military was positive and not in the expected direction. The GT score was not significantly weighted in the equation. The multiple correlation between the average fire time in the experimental conditions and the set of experience variables was also significant ($R=.46$, $R^2=.21$, $F(4,42)=2.80$; $p=.038$). Two constituent variables were significantly weighted in the regression equation: time as gunner ($t[42]=-2.14$; $p=.038$) and time in military ($t[42]=2.26$; $p=.029$). Once again,

the Beta weight for time as gunner was negative and in the expected direction, however, the Beta weight for time in military was positive and not in the expected direction. The GT score was not significant when entered into the equation. There were no significant multiple correlations between percent hits and aiming error and the biographical variables. (See Table 14 for details of the multiple regression analyses.)

Table 13

Pearson Correlations between Performance Measures on the Pretest and in the Experimental Conditions and Biographical Variables for Experiment II

	Time in Military	Time in Armor	Time as Gunner	GT Score	Hours on UCOFT
Pretest Fire Time	.5048 (48) p=.000	.4448 (48) p=.001	-.2727 (48) p=.030	.1331 (47) p=.186	-.2093 (48) p=.077
Pretest Percent Hits	-.2151 (48) p=.071	-.2223 (48) p=.064	.0694 (48) p=.320	.2028 (47) p=.086	.2710 (48) p=.031
Pretest Aiming Error	.1258 (48) p=.197	.0278 (48) p=.426	-.1737 (48) p=.119	-.1732 (47) p=.122	-.2291 (48) p=.059
Experiment Fire Time	.3071 (48) p=.017	.1470 (48) p=.163	-.3156 (48) p=.014	.0370 (47) p=.403	.0031 (48) p=.492
Experiment Percent Hits	-.0416 (48) p=.389	.0977 (48) p=.254	-.0114 (48) p=.469	-.0898 (47) p=.274	.0607 (48) p=.341
Experiment Aiming Error	-.0697 (48) p=.319	-.2520 (48) p=.042	-.0890 (48) p=.274	-.0493 (47) p=.371	-.1392 (48) p=.178

Table 14

Results of Multiple Regression Analyses of Performance Measures by the Biographical Variables for Experiment II

	Multiple R	R^2	R^2 Change	F	df	p level	Beta	t	p level
Pretest Fire Time									
Set of Experience Variables	.63	.40	.40	6.91	4,42	.000			
GT Score	.65	.42	.02	1.77	5,41	ns			
Variables in the Equation:									
Time in Military							.402	2.05	.047
Time in Armor							.181	0.93	ns
Time as Gunner							-.258	-2.14	.038
Hours on UCOFT							-.194	-1.59	ns
GT Score							.164	1.33	ns
Overall Model				5.98	5,41	.000			
Experiment Fire Time									
Set of Experience Variables	.46	.21	.21	2.80	4,42	.038			
GT Score	.46	.21	.00	0.25	5,41	ns			
Variables in the Equation:									
Time in Military							.518	2.26	.029
Time in Armor							-.249	-1.09	ns
Time as Gunner							-.300	-2.14	.038
Hours on UCOFT							.037	0.26	ns
GT Score							.072	0.50	ns
Overall Model				2.25	5,41	.067			

Note. p levels > .10 = not significant (ns)

Table 14 (Continued)

Results of Multiple Regression Analyses of Performance Measures by the Biographical Variables for Experiment II

	Multiple R	R^2	R^2 Change	F	df	p level	Beta	t	p level
Pretest Percent Hits									
Set of Experience Variables	.39	.15	.15	1.89	4,42	ns			
GT Score	.45	.20	.05	2.66	5,41	ns			
Variables in the Equation:									
Time in Military							.036	0.16	ns
Time in Armor							-.267	-1.17	ns
Time as Gunner							.081	0.57	ns
Hours on UCOFT							.339	2.37	.023
GT Score							.236	1.63	ns
Overall Model				2.10	5,41	.085			
Experiment Percent Hits									
Set of Experience Variables	.21	.05	.05	0.50	4,42	ns			
GT Score	.25	.06	.01	0.66	5,41	ns			
Variables in the Equation:									
Time in Military							-.358	-1.43	ns
Time in Armor							.358	1.43	ns
Time as Gunner							-.014	-0.92	ns
Hours on UCOFT							-.026	-0.17	ns
GT Score							-.128	-0.81	ns
Overall Model				0.53	5,41	ns			

Note. p levels > .10 = not significant (ns)

Table 14 (Continued)

Results of Multiple Regression Analyses of Performance Measures by the Biographical Variables for Experiment II

	Multiple R	R^2	R^2 Change	F	df	p level	Beta	t	p level
Pretest Aiming Error									
Set of Experience Variables	.34	.11	.11	1.39	4,42	ns			
GT Score	.39	.15	.04	1.79	5,41	ns			
Variables in the Equation:									
Time in Military							.198	0.83	ns
Time in Armor							-.108	-0.46	ns
Time as Gunner							-.190	-1.31	ns
Hours on UCOFT							-.238	-1.62	ns
GT Score							-.199	-1.34	ns
Overall Model				1.49	5,41	ns			
Experiment Aiming Error									
Set of Experience Variables	.29	.09	.09	0.99	4,42	ns			
GT Score	.29	.09	.00	0.00	5,41	ns			
Variables in the Equation:									
Time in Military							.237	0.96	ns
Time in Armor							-.383	-1.56	ns
Time as Gunner							-.123	-0.81	ns
Hours on UCOFT							-.048	-0.31	ns
GT Score							-.003	-0.19	ns
Overall Model				0.78	5,41	ns			

Note. p levels > .10 = not significant (ns)

Discussion

The results of this experiment revealed a significant overall effect for emergency mode on gunner performance while no effects for MOPP gear were indicated on any performance measure. The significant effect for MOPP gear on aiming error found in Experiment I was not replicated in this experiment. Emergency mode significantly degraded all three performance measures: fire time, percent hits, and aiming error. Furthermore, no significant interaction between MOPP gear and operational mode existed. The nonsignificant interaction indicates that MOPP gear did not additionally affect performance when under emergency operational conditions. Emergency mode remained the only significant effect on gunner performance.

The results of this experiment also suggest that the degrading effects of emergency mode may depend upon situational characteristics. For example, emergency mode only affected fire time in long range target engagements. Aiming error was affected by emergency mode in the moving target exercise with no significant effect in the stationary target exercise. Another result indicated significant effects for emergency mode on aiming error in the stationary own tank/moving target exercise and no significant effect for emergency mode in the moving own tank/moving target exercise. These results support the conclusions of Experiment I. Performance decrements cannot be assumed for all target engagements.

The multiple correlations once again suggested a relationship between fire time and experience, while the accuracy measures of percent hits and aiming error were not significantly correlated with experience. The positive direction of the Beta weight for time in military, however, suggests a totally different relationship with fire time. The positive direction indicates that as time in the military increases, fire time increases, hence, the slower the gunner's speed at firing a round of ammunition. This is contradictory to the negative relationship between fire time and time as gunner.

GENERAL DISCUSSION

This research was designed to examine and identify possible deficiencies in Armor crewmen performance while wearing NBC equipment under normal and degraded operational conditions. Previous research has revealed large performance decrements associated with NBC protective equipment (Muza, 1986). The performance degradation largely corresponds to visual limitations due to the restrictions imposed by the mask and loss of manual dexterity when wearing the rubber gloves. Research indicates that measures of speed may be affected while accuracy is not (Fine & Kobrick, 1986; Rauch et al., 1986). Existing research on tank crewmen under NBC conditions has focused on performance decrements due to the physiological effects of fatigue and heat stress from sustained operations in complete MOPP gear corresponding to the MOPP4 level (Carr, et al., 1980). Because tank gunnery relies heavily on visual capability and manual dexterity, it is imperative to investigate and identify the effects of MOPP gear on psychomotor responses in gunnery performance while controlling for fatigue and heat stress. Future battlefield conditions can result in malfunctions in the tank's normal operational mode, therefore,

examining the effects of MOPP gear in normal and degraded operational conditions is warranted.

Results of this research did not support previous indications of large performance decrements associated with NBC equipment. The only significant effect for MOPP gear was for aiming error in Experiment I. However, this finding was not replicated in Experiment II. In Experiment II, the only significant result was the degrading effect of emergency operational mode on all performance measures. There were also no significant interactions between MOPP gear and operational mode. This result suggests that MOPP gear did not affect nor further degrade performance under emergency operational conditions as might be expected. As Muza (1986) suggested, the effectiveness of weapon or surveillance systems should decline because the protective mask hinders the alignment of the eye with the optical sight. However, alignment of the eye with a weapon system's optical sight constitutes a narrow field of view. Hence, ". . . performance of certain tasks may be enhanced by CB [chemical, biological] mask wear . . . the narrower field of view may eliminate distractions and help the soldier concentrate on his task" (Muza, 1986, p. 18). The results of this research support Muza's suggestions, but should be further investigated for more conclusive evidence.

A factor which may have affected the results for MOPP gear is the experience level of the subjects. They were highly qualified and experienced Armor personnel. They were instructors from the M1 NETT team, trained to instruct M1 gunnery and conduct of fire procedures. On the average, the subjects had more than 12 years of time in the military and more than two years overall time as gunner. These qualifications alone suggest experience as a possible factor in their successful performance. The multiple correlation between fire time and the experience variables, particularly time as gunner, was significant. The negative direction of the correlation for time as gunner was expected. Gunners should become faster at firing a round of ammunition as their experience as a gunner increases. However, the correlation between fire time and time in military, while significant, was positive. The relationship may be due to the slowing of response times with age which has been found in numerous research concerning aging effects on motor behavior (Hodgkins, 1962; Noble, 1978; Schmidt, 1982). "One simple generalization is that past the age of about 25 years, a progressive decline occurs in just about every measurable aspect of motor behavior . . . one of the most consistent findings in the aging literature is that people become slower with age" (Schmidt, 1982, pp. 426-427). Therefore, the positive direction of the correlation may simply support previous reaction time research.

The positive results for MOPP gear on gunner performance in this sample of experienced armor personnel support the conclusion of Fine and Kobrick (1986). Fine and Kobrick (1986) examined the sustained performance of trained personnel in complete MOPP gear on military tasks routinely performed during an NBC attack. The subjects were exposed to heat stress and a control condition with cooler temperatures and lower humidity. From their results, Fine and Kobrick concluded that ". . . very well trained soldiers in MOPP4, sedentary, and performing cognitive tasks in relatively moderate heat and humidity conditions, on the whole will probably function effectively for up to three hours . . ." (, age 20). Their results indicated a dramatic drop in subjects' performance after four to five hours of heat exposure while in the

MOPP4 level of NBC protection. However, heat stress appeared to be a more decisive factor in the performance decrement than the MOPP gear alone. After seven hours, the overall performance of subjects in MOPP4 when exposed to cooler temperatures was not significantly different from their performance in the control condition when not wearing MOPP gear. Therefore, the results of Fine and Kobrick and this research project suggest that MOPP gear alone does not necessarily result in large performance deficiencies. It appears to be the combination of wearing MOPP gear during sustained operations and exposure to hot and humid conditions that impairs performance.

Training in MOPP gear under NBC conditions is highly stressed in today's Army. Presently, "our adversary is better equipped and trained to operate under NBC conditions than we are and could capitalize upon such an advantage in military operations" (Moffett, 1981, p. 38). The solution to this problem lies in training for the future battlefield during peacetime. In order to minimize the threat of NBC weapons and reduce the performance degradation associated with protective equipment, soldiers must periodically train in MOPP gear under NBC conditions. Success on the modern battlefield will require the soldier to conduct operations and accomplish his mission in protective equipment. "Unless the unit is well-trained and conditioned in NBC protective operations, the loss of operational effectiveness . . . will have an adverse effect on mission accomplishment" (FM 17-17, p. E-17). Well trained and thus well-prepared soldiers will suffer less overall stress when using MOPP gear in combat. Therefore, training under NBC conditions in MOPP gear is the key to reducing casualties in actual combat and increasing operational effectiveness. "Training is the cornerstone of success . . . on the day of battle, soldiers and units will fight as well or as poorly as they were trained before battle" (FM 100-5, p. 1-4).

Considering the extensive amount of time in the military and in Armor, and overall time as gunner for this sample of subjects, it is not unrealistic to assume that the majority have received a fair amount of NBC training. Their successful performance while wearing MOPP gear may be a reflection of their previous training. A number of subjects informed the researcher that they had received a large amount of training in MOPP gear. However, no objective data were collected for confirmation. Therefore, the validity of this hypothesis awaits determination by research using less experienced Armor crewmen and obtaining quantitative data on NBC training.

Extensive training under degraded operational conditions appears mandatory to offset the performance deficiencies revealed in this research. For mission accomplishment, soldiers should be trained under all potential conditions faced on the modern battlefield including limitations in operational readiness. The UCOFT training matrix includes exercises specifically designed for training under various degraded operational conditions. Therefore, UCOFT training should be considered a crit cal component in training countermeasures designed to alleviate the level of degradation associated with future battlefield conditions. As Fine and Kobrick (1986) stressed, the consequence of overlearning routine tasks in realistic military scenarios is well-trained soldiers.

In summary, the results of this research indicated no substantial deficiencies in gunnery performance associated with the protective mask and

gloves in this sample of subjects. At the same time, deficiencies existed when gunners were required to perform under less than optimal operational conditions. A number of factors could have affected the positive results for MOPP gear which require further investigation. The performance degradation associated with emergency operational mode strongly suggests the development of intensive training countermeasures to moderate the impact of possible battlefield threats on the gunner's proficiency. Realistic training in peacetime results in real soldier preparedness.

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APPENDIX A

LISTING OF EXERCISES - EXPERIMENT I

PRETEST EXERCISES

Conditions - Fully Operational Tank
Normal Operational Mode
Day Unlimited Visibility
Single Targets

UCOFT Exercise Number

31111(0) - Stationary Own Tank/Short Range Stationary Target
32111(0) - Stationary Own Tank/Long Range Stationary Target
31311(0) - Stationary Own Tank/Short Range Moving Target
32311(0) - Stationary Own Tank/Long Range Moving Target
31411(1) - Moving Own Tank/Short Range Stationary Target
32411(0) - Moving Own Tank/Long Range Stationary Target
31511(0) - Moving Own Tank/Short Range Moving Target
32511(1) - Moving Own Tank/Long Range Moving Target

EXPERIMENTAL CONDITIONS

Conditions -

Groups 1, 2, 3: Fully Operational Tank
Normal Operational Mode
Day Unlimited Visibility
Single Targets

Group 4: Computer, Laser Range Finder, Stabilization System, and Gunner Primary Sight - Nonfunctional
Emergency Operational Mode
Day Unlimited Visibility
Single Targets

UCOFT Exercise Number

32131(0) - Stationary Own Tank/Long Range Stationary Target
31431(0) - Moving Own Tank/Short Range Stationary Target
32431(0) &
32431(1) - Moving Own Tank/Long Range Stationary Target
31331(0) - Stationary Own Tank/Short Range Moving Target
32331(0) - Stationary Own Tank/Long Range Moving Target
31531(0) - Moving Own Tank/Short Range Moving Target

APPENDIX B

INSTRUCTIONS TO SUBJECTS

The purpose of this research project is to determine how gunnery performance is affected by degraded engagement conditions and MOPP gear. You will be required to engage a series of computer-generated targets on the UCOFT under normal or degraded conditions. Prior to engaging these targets you will perform warm-up exercises to introduce you to the UCOFT. Questions about the UCOFT or about experimental procedures should be asked during the warm-up exercises. After the warm-up you will be given a 10-minute break and will complete a biographical questionnaire. You will then return to the UCOFT to perform the test exercises. Those of you who will be in MOPP will then put on the appropriate gear. For the test, you will perform two sets of three exercises each, separated by a 10-minute break. No assistance will be provided by the UCOFT Instructor/Operator or by the TC on the test.

The UCOFT presents both offensive and defensive scenarios. In the offensive scenarios you will usually shoot with your tank on the move. In the defensive engagements, your tank moves up from behind a berm, stops, and then fires while stationary. Your instructor/operator will inform you prior to an exercise whether you are in an offensive or defensive posture.

The UCOFT is capable of simulating both normal and degraded conditions. The instructor/operator will inform you of the system degradation if it exists for each exercise prior to the start of the exercise. The instructor/operator will also instruct you on the switch settings for the exercise and indicate the procedures to be used in that exercise.

As each target is presented, your TC will lay the gun on a landmark near the target and issue a fire command. Because fire commands will vary from one engagement to the next, you must listen very carefully to each fire command. When you hear the TC command, you should search for the target with your GPS or GAS, and announce IDENTIFIED upon acquiring the target. When you detect a target with the GPS, you should switch the GPS to 10X, lay on the target, track it if it is moving, and fire upon the TC's command announcing ON THE WAY when you fire. Your speed and accuracy of engaging targets is important and will be measured for each engagement. When you hit a target, a white flash occurs at the target, its normal motion ceases, and it assumes a killed posture. If you miss a target dirt will be kicked up. If you fail to kill the target in the allotted time (18 to 24 seconds), all sights will go black and controls will be inoperative for five seconds to indicate that you were killed. The gun select switch will return to the TRIGGER SAFE position when you are killed and must be reset to the MAIN GUN position prior to firing the next engagement.

APPENDIX C

BIOGRAPHICAL DATA - EXPERIMENT I

Table C.1

Biographical Summary Data by Group for Experiment I

Group[a]	ASVAB GT Score	Time/Military (months)	Time/Armor (months)	Time/Gunner (months)	Time/UCOFT (hours)
1. No MOPP Normal Operational Mode					
M	106.45	147.58	135.33	26.17	53.33
SD	9.09	35.95	44.96	22.51	75.74
2. Mask Only Normal Operational Mode					
M	111.75	143.75	127.42	25.25	52.08
SD	15.32	46.14	36.62	20.72	76.28
3. Mask and Gloves Normal Operational Mode					
M	110.75	137.67	130.50	24.50	14.42
SD	14.35	55.32	48.79	12.24	27.76
4. Mask and Gloves Emergency Operational Mode					
M	106.33	131.00	119.58	23.50	35.67
SD	11.59	25.85	38.59	15.49	51.85
Total Sample					
M	108.87	140.00	128.21	24.85	38.88
SD	12.72	41.39	41.54	17.64	61.38

[a] n = 12 per group.

APPENDIX D

BIOGRAPHICAL QUESTIONNAIRE

Subject # _____ Group _____ Date _____

1. Age _____ years

2. Grade E-_____

3. Education level. Circle one.

   a. less than 12 years b. GED c. high school graduate

   d. technical school e. some college ___ years

   f. college graduate g. other (describe) _____

4. General Technical (GT) Score _____ Social Security No. _____

5. Total time in service _____ years _____ mos.

6. How long have you been in Armor? _____ years _____ mos.

7. Present crew position _____ Time in position _____ mos.

   Present vehicle _____

8. Time spent as a gunner _____ mos. Time as M1 gunner ____ mos.

   Time as M60A3 gunner _____ mos. Other gunnery time _____ Vehicle _____

9. When was your last training/sustainment gunnery practice? _____ mos. (Exclude COFT)

10. On how many separate occasions have you fired the COFT? _____ Hours on COFT _____

APPENDIX E
PRETEST PERFORMANCE - EXPERIMENT I

Table E.1

Means and Standard Deviations on Pretest by Assigned Experimental Group for Experiment I

Group[a]		Fire Time (seconds)	Percent Hits	Aiming Error (mils)
1.	No MOPP Normal Operational Mode			
	M	14.21	69.84	1.47
	SD	1.52	16.66	0.43
2.	Mask Only Normal Operational Mode			
	M	14.44	84.69	1.02
	SD	2.27	9.48	0.24
3.	Mask and Gloves Normal Operational Mode			
	M	14.73	71.78	1.35
	SD	2.17	17.20	0.42
4.	Mask and Gloves Emergency Operational Mode			
	M	13.70	78.42	1.13
	SD	1.53	14.33	0.26
	Total Sample			
	M	14.27	76.18	1.24
	SD	1.88	15.44	0.38

Note. Pretest was performed without MOPP gear and under normal operational mode conditions by all groups.
Fire time is the time elapsed from full target exposure to when the gunner fires.
Percent hits = (number of hits/number of targets presented) x 100.
Aiming error = square root [(azimuth error)^2 + (elevation error)^2].

[a] n = 12 per group.

APPENDIX F

INTERCORRELATIONS AMONG PERFORMANCE MEASURES - EXPERIMENT I

Table F.1

Pearson Intercorrelations on Performance Measures on the Pretest and in the Experimental Conditions for Experiment I

	Pretest Fire Time	Pretest Percent Hits	Pretest Aiming Error	Experiment Fire Time	Experiment Percent Hits
Pretest Percent Hits	-.3044 (48) p=.018				
Pretest Aiming Error	.1704 (48) p=.123	-.8247 (48) p=.000			
Experiment Fire Time	.6153 (48) p=.000	-.1087 (48) p=.231	-.0278 (48) p=.426		
Experiment Percent Hits	-.0744 (48) p=.308	.2528 (48) p=.041	-.2529 (48) p=.041	-.4625 (48) p=.000	
Experiment Aiming Error	-.1307 (48) p=.188	-.1068 (48) p=.235	.1835 (48) p=.106	.2488 (48) p=.044	-.6786 (48) p=.000

APPENDIX G

SUMMARY DATA ON PERFORMANCE MEASURES - EXPERIMENT I

Table G.1

Means and Standard Deviations for Fire Time on each Exercise by Group for Experiment I

Group[a]		Exercise 1 Stationary Tank Stationary Target Long Range	2 Moving Tank Stationary Target Short Range	3 Moving Tank Stationary Target Long Range	4 Stationary Tank Moving Target Short Range
1. No MOPP Normal Operational Mode					
	M	14.24	10.10	13.08	14.38
	SD	2.48	2.50	2.84	1.45
2. Mask Only Normal Operational Mode					
	M	16.03	11.48	15.32	15.23
	SD	2.59	2.21	3.20	2.00
3. Mask and Gloves Normal Operational Mode					
	M	14.41	10.44	13.31	15.09
	SD	2.32	2.24	2.38	2.14
4. Mask and Gloves Emergency Operational Mode					
	M	18.08	10.97	16.02	15.38
	SD	2.02	1.42	2.95	2.33
Total Sample					
	M	15.69	10.75	14.43	15.02
	SD	2.77	2.13	3.05	1.98

Note. Fire time is the elapsed time (seconds) from full target exposure to when the gunner fires.

[a] n = 12 per group.

Table G.1 (Continued)

Means and Standard Deviations for Fire Time on each Exercise by Group for Experiment I

Group[a]	Exercise 5 Stationary Tank Moving Target Long Range	Exercise 6 Moving Tank Moving Target Short Range	Exercise Mean
1. No MOPP Normal Operational Mode			
M	15.36	12.82	13.33
SD	1.69	2.42	1.84
2. Mask Only Normal Operational Mode			
M	16.06	12.65	14.46
SD	3.42	2.27	2.06
3. Mask and Gloves Normal Operational Mode			
M	16.30	11.94	13.58
SD	3.04	1.85	1.96
4. Mask and Gloves Emergency Operational Mode			
M	18.23	13.58	15.37
SD	2.49	1.95	1.69
Total Sample			
M	16.49	12.75	14.19
SD	2.86	2.15	2.00

Note. Fire time is the elapsed time (seconds) from full target exposure to when the gunner fires.

[a] n = 12 per group.

Table G.2

Means and Standard Deviations for Percent Hits on each Exercise by Group for Experiment I

Group[a]		Exercise 1 Stationary Tank Stationary Target Long Range	Exercise 2 Moving Tank Stationary Target Short Range	Exercise 3 Moving Tank Stationary Target Long Range	Exercise 4 Stationary Tank Moving Target Short Range
1. No MOPP Normal Operational Mode	M	93.89	94.79	70.46	82.75
	SD	7.19	11.25	17.23	16.99
2. Mask Only Normal Operational Mode	M	87.96	89.38	74.88	85.19
	SD	15.06	14.39	13.98	11.92
3. Mask and Gloves Normal Operational Mode	M	94.17	90.63	76.67	83.27
	SD	9.00	13.19	24.98	9.78
4. Mask and Gloves Emergency Operational Mode	M	77.92	89.29	80.28	59.54
	SD	18.21	9.54	13.95	24.95
Total Sample	M	88.48	91.02	75.57	77.69
	SD	14.35	12.05	17.88	19.54

Note. Percent hits = (number of hits/number of targets presented) x 100.

[a] n = 12 per group.

Table G.2 (Continued)

Means and Standard Deviations for Percent Hits on each Exercise by Group for Experiment I

Group[a]	Exercise 5 Stationary Tank Moving Target Long Range	Exercise 6 Moving Tank Moving Target Short Range	Exercise Mean
1. No MOPP Normal Operational Mode			
M	52.55	79.17	78.94
SD	16.81	9.44	9.42
2. Mask Only Normal Operational Mode			
M	62.40	78.13	79.66
SD	16.49	13.38	4.41
3. Mask and Gloves Normal Operational Mode			
M	54.22	84.14	80.51
SD	23.51	14.54	3.83
4. Mask and Gloves Emergency Operational Mode			
M	17.66	65.39	65.01
SD	12.06	18.04	8.56
Total Sample			
M	46.71	76.71	76.03
SD	24.39	15.40	9.75

Note. Percent hits = (number of hits/number of targets presented) x 100.

[a] n = 12 per group.

Table G.3

Means and Standard Deviations for Aiming Error on each Exercise by Group for Experiment I

Group[a]	Exercise 1 Stationary Tank Stationary Target Long Range	2 Moving Tank Stationary Target Short Range	3 Moving Tank Stationary Target Long Range	4 Stationary Tank Moving Target Short Range
1. No MOPP Normal Operational Mode				
M	0.54	0.75	1.14	1.16
SD	0.13	0.25	0.29	0.42
2. Mask Only Normal Operational Mode				
M	0.61	0.85	1.24	1.13
SD	0.44	0.28	0.42	0.27
3. Mask and Gloves Normal Operational Mode				
M	0.54	0.80	1.36	1.39
SD	0.17	0.21	0.83	0.93
4. Mask and Gloves Emergency Operational Mode				
M	0.53	0.70	0.94	1.83
SD	0.25	0.12	0.46	0.57
Total Sample				
M	0.56	0.78	1.17	1.38
SD	0.27	0.22	0.54	0.65

Note. Aiming error (mils) = square root [(azimuth error)^2 + (elevation error)^2].

[a] n = 12 per group.

Table G.3 (Continued)

Means and Standard Deviations for Aiming Error Time on each Exercise by Group for Experiment I

Group[a]	Exercise 5 Stationary Tank Moving Target Long Range	Exercise 6 Moving Tank Moving Target Short Range	Exercise Mean
1. No MOPP Normal Operational Mode			
M	1.61	1.81	1.17
SD	0.62	0.33	0.24
2. Mask Only Normal Operational Mode			
M	1.97	1.84	1.27
SD	1.86	0.35	0.29
3. Mask and Gloves Normal Operational Mode			
M	1.62	1.69	1.23
SD	0.71	0.43	0.22
4. Mask and Gloves Emergency Operational Mode			
M	3.82	1.52	1.56
SD	1.23	0.46	0.26
Total Sample			
M	2.25	1.72	1.31
SD	1.49	0.40	0.29

Note. Aiming error (mils) = square root [(azimuth error)^2 + (elevation error)^2].

[a] n = 12 per group.

APPENDIX H

INTERCORRELATIONS AMONG BIOGRAPHICAL VARIABLES - EXPERIMENT I

Table H.1

Pearson Intercorrelations on Biographical Variables for Experiment I

	Time in Military	Time in Armor	Time as Gunner	GT Score
Time in Armor	.8260 (48) p=.000			
Time as Gunner	-.2008 (48) p=.086	-.0809 (48) p=.292		
GT Score	-.0286 (47) p=.424	-.0248 (47) p=.434	.0134 (47) p=.464	
Hours on UCOFT	-.1102 (48) p=.228	-.0142 (48) p=.462	-.0083 (48) p=.478	-.1309 (47) p=.190

APPENDIX I

LISTING OF EXERCISES - EXPERIMENT II

PRETEST EXERCISES

Conditions - Fully Operational Tank
Normal Operational Mode
Day Unlimited Visibility
Single Targets

UCOFT Exercise Number

31111(0) & 31211(0) - Stationary Own Tank/Short Range Stationary Target
32111(0) & 32211(0) - Stationary Own Tank/Long Range Stationary Target
31311(0) & 31331(1) - Stationary Own Tank/Short Range Moving Target
32311(0) & 32331(1) - Stationary Own Tank/Long Range Moving Target
31511(0) & 31531(0) - Moving Own Tank/Short Range Moving Target
32511(1) & 32531(0) - Moving Own Tank/Long Range Moving Target

EXPERIMENTAL CONDITIONS

Conditions -

Groups 1, 3: Fully Operational Tank
Normal Operational Mode
Day Unlimited Visibility
Single Targets

Groups 2, 4: Computer, Laser Range Finder, Stabilization System, and Gunner Primary Sight - Nonfunctional
Emergency Operational Mode
Day Unlimited Visibility
Single Targets

UCOFT Exercise Number

31531(0) & 31511(0) - Moving Own Tank/Short Range Moving Target
32131(0) & 32111(0) - Stationary Own Tank/Long Range Stationary Target
31331(0) & 31311(0) - Stationary Own Tank/Short Range Moving Target
32331(0) & 32311(0) - Stationary Own Tank/Long Range Moving Target

APPENDIX J
PRETEST PERFORMANCE - EXPERIMENT II

Table J.1

Means and Standard Deviations on Pretest by Assigned Experimental Group for Experiment II

Group[a]		Fire Time (seconds)	Percent Hits	Aiming Error (mils)
1.	No MOPP Normal Operational Mode			
	M	15.12	63.72	1.57
	SD	1.72	20.39	0.48
2.	No MOPP Emergency Operational Mode			
	M	14.41	71.02	1.47
	SD	2.06	11.84	0.41
3.	Mask and Gloves Normal Operational Mode			
	M	15.74	65.59	1.40
	SD	2.25	19.71	0.52
4.	Mask and Gloves Emergency Operational Mode			
	M	14.72	73.33	1.15
	SD	1.69	16.45	0.31
	Total Sample			
	M	14.99	68.42	1.39
	SD	1.95	17.32	0.45

Note. Pretest was performed without MOPP gear and under normal operational mode conditions by all groups. Fire time is the elapsed time from full target exposure to when the gunner fires. Percent hits = (number of hits/number of targets presented) x 100. Aiming error = square root $[(\text{azimuth error})^2 + (\text{elevation error})^2]$.

[a] n = 12 per group.

APPENDIX K

INTERCORRELATIONS AMONG PERFORMANCE MEASURES - EXPERIMENT II

Table K.1

Pearson Intercorrelations on Performance Measures on the Pretest and in the Experimental Conditions for Experiment II

	Pretest Fire Time	Pretest Percent Hits	Pretest Aiming Error	Experiment Fire Time	Experiment Percent Hits
Pretest Percent Hits	-.3830 (48) p=.004				
Pretest Aiming Error	.1947 (48) p=.092	-.7780 (48) p=.000			
Experiment Fire Time	.4099 (48) p=.002	-.0414 (48) p=.390	-.0468 (48) p=.376		
Experiment Percent Hits	-.0119 (48) p=.468	-.0195 (48) p=.448	.0113 (48) p=.470	-.6054 (48) p=.000	
Experiment Aiming Error	-.1234 (48) p=.202	-.0380 (48) p=.399	-.0266 (48) p=.429	.4183 (48) p=.002	-.7721 (48) p=.000

APPENDIX L

SUMMARY DATA ON PERFORMANCE MEASURES - EXPERIMENT II

Table L.1

Means and Standard Deviations for Fire Time on each Exercise by Group for Experiment II

Group[a]		Exercise 1 Moving Tank Moving Target Short Range	Exercise 2 Stationary Tank Stationary Target Long Range	Exercise 3 Stationary Tank Moving Target Short Range	Exercise 4 Stationary Tank Moving Target Long Range	Exercise Mean
1. No MOPP Normal Operational Mode	M	12.82	14.24	14.38	15.36	14.20
	SD	2.42	2.48	1.45	1.69	1.74
2. No MOPP Emergency Operational Mode	M	13.79	18.47	14.87	17.23	16.09
	SD	1.63	1.89	1.57	1.57	1.15
3. Mask and Gloves Normal Operational Mode	M	11.94	14.41	15.07	16.30	14.43
	SD	1.85	2.32	2.12	3.03	1.97
4. Mask and Gloves Emergency Operational Mode	M	13.58	18.08	15.38	18.23	16.32
	SD	1.95	2.02	2.33	2.49	1.93
Total Sample	M	13.03	16.29	14.92	16.78	15.26
	SD	2.06	2.91	1.88	2.46	1.93

Note. Fire time is the time elapsed (seconds) from full target exposure to when the gunner fires.

[a] n = 12 per group.

Table L.2

Means and Standard Deviations for Percent Hits on each Exercise by Group for Experiment II

Group[a]	Exercise 1 Moving Tank Moving Target Short Range	2 Stationary Tank Stationary Target Long Range	3 Stationary Tank Moving Target Short Range	4 Stationary Tank Moving Target Long Range	Exercise Mean
1. No MOPP Normal Operational Mode					
M	79.98	95.65	82.87	53.13	77.91
SD	9.72	8.59	17.85	17.04	9.30
2. No MOPP Emergency Operational Mode					
M	61.67	59.95	53.70	25.00	50.08
SD	14.03	23.36	15.67	15.67	8.90
3. Mask and Gloves Normal Operational Mode					
M	84.14	94.17	82.34	54.22	78.72
SD	14.54	9.00	8.49	23.51	10.26
4. Mask and Gloves Emergency Operational Mode					
M	65.39	77.92	53.59	17.66	53.64
SD	18.04	18.21	22.85	12.06	10.37
Total Sample					
M	72.79	81.92	68.13	37.50	65.09
SD	16.89	21.34	22.03	23.73	16.40

Note. Percent hits = (number of hits/number of targets presented) x 100.

[a] n = 12 per group.

Table L.3

Means and Standard Deviations for Aiming Error on each Exercise by Group for Experiment II

Group[a]	Exercise 1 Moving Tank Moving Target Short Range	2 Stationary Tank Stationary Target Long Range	3 Stationary Tank Moving Target Short Range	4 Stationary Tank Moving Target Long Range	Exercise Mean
1. No MOPP Normal Operational Mode					
M	1.81	0.54	1.16	1.61	1.28
SD	0.33	0.13	0.42	0.62	0.26
2. No MOPP Emergency Operational Mode					
M	2.03	0.73	1.76	3.29	1.95
SD	0.55	0.34	0.40	0.94	0.33
3. Mask and Gloves Normal Operational Mode					
M	1.69	0.54	1.39	1.62	1.31
SD	0.43	0.17	0.93	0.71	0.26
4. Mask and Gloves Emergency Operational Mode					
M	1.52	0.53	1.83	3.82	1.93
SD	0.46	0.25	0.57	1.23	0.35
Total Sample					
M	1.76	0.59	1.54	2.59	1.62
SD	0.47	0.24	0.66	1.33	0.44

Note. Aiming error (mils) = square root [(azimuth error)^2 + (elevation error)^2].

[a] n = 12 per group.

APPENDIX M

BIOGRAPHICAL DATA - EXPERIMENT II

Table M.1

Biographical Summary Data by Group for Experiment II

Group[a]		ASVAB GT Score	Time/Military (months)	Time/Armor (months)	Time/Gunner (months)	Time/UCOFT (hours)
1.	No MOPP Normal Operational Mode					
	M	106.45	147.58	135.33	26.17	54.17
	SD	9.09	35.95	44.96	22.51	75.39
2.	No MOPP Emergency Operational Mode					
	M	116.83	128.58	107.25	28.33	19.08
	SD	13.73	32.22	32.78	17.43	40.25
3.	Mask and Gloves Normal Operational Mode					
	M	110.75	137.67	130.50	24.50	15.67
	SD	14.35	55.32	48.79	12.24	28.13
4.	Mask and Gloves Emergency Operational Mode					
	M	106.33	131.00	119.58	23.50	35.67
	SD	11.59	25.85	38.59	15.49	51.85
	Total Sample					
	M	110.17	136.21	123.17	25.63	31.15
	SD	12.78	38.38	41.83	16.86	52.56

[a] n = 12 per group.

APPENDIX N

INTERCORRELATIONS AMONG BIOGRAPHICAL VARIABLES - EXPERIMENT II

Table N.1

Pearson Intercorrelations on Biographical Variables for Experiment II

	Time in Military	Time in Armor	Time as Gunner	GT Score
Time in Armor	.7862 (48) p=.000			
Time as Gunner	.0076 (48) p=.480	.0338 (48) p=.410		
GT Score	-.1805 (47) p=.112	-.0886 (47) p=.277	-.1360 (47) p=.181	
Hours on UCOFT	.0328 (48) p=.412	.1302 (48) p=.189	.0272 (48) p=.427	-.1167 (47) p=.217