ARMY RESEARCH LABORATORY

The Effect of Continuous Operations and Various Secondary Task Displays on Soldier Shooting Performance

by David R. Scribner, Patrick H. Wiley, and William H. Harper

ARL-TR-4268 **September 2007**

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14. ABSTRACT

Soldiers will be required to perform missions with advanced information displays as the Army transforms. Soldiers will also be placed under a range of environmental stressors including continuous operations. The need to provide an information display that is operable during extended stressful conditions is crucial to the mission success of the Soldier. Optimal Soldier-system performance is desired to maximize performance and minimize errors for the end result of increased Soldier survivability and lethality. This study was performed at the U.S. Army Research Laboratory's Human Research and Engineering Directorate shooting simulator facility. The study examined the the presentation of secondary task workload via an auditory display and two visual display conditions. There was also a no-workload shooting condition. The two visual display conditions consisted of a forearm-mounted display (FMD) and a helmet-mounted display (HMD), both configured with an auditory alert cue that informed the Soldier of a new math problem appearing on the display screen. Soldiers were asked to complete a secondary workload task consisting of arithmetic problems while engaged in a friend-or-foe shooting scenario with various stages of sleep deprivation. Data were collected every 6 hours for periods of 0 through 30 hours of sleeplessness. This study examined (a) the shooting performance of Soldiers during all conditions including shoot/do-not-shoot decisions, hit percentage, and response time, (b) the ability of Soldiers to complete secondary tasks in each display mode in a single and dual task paradigm, and (c) the ability of Soldiers to perform these single and dual task shooting scenarios continually for 30 hours without sleep. Participants were 12 U.S. Army Soldiers recruited from the 143rd Ordnance Batallion at Aberdeen Ground, Maryland. The shooting task consisted of a 24-target pop-up scenario with friendly and enemy E-type silhouette targets. Analyses of variance revealed significant simple and interaction effects.

15. SUBJECT TERMS
continuous operations; displays; secondary task; shooting performance

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1. Introduction

The U.S. Army is continually trying to assess Soldier performance during various conditions and with new equipment. One of the Army's challenges for the dismounted Soldier is to optimize Soldier combat performance, considering the impact of processing additional information. Additionally, the Army is trying to fight the effect of continuous operations on Soldier duties, including dismounted enemy engagement. The purpose of this study was to examine the effects of various displays for shooting task and secondary task performance during 30 hours of continuous operation.

1.1 Multi-Tasking During Shooting

Increased cognitive tasking is inevitable because of the expansion of digital command and control (C2) systems in the Army, and many tasks will be performed simultaneously with shooting tasks. Multi-tasking, in its most demanding and crucial form for the dismounted infantry Soldier, is a scenario where a Soldier is shooting or being shot at while having to attend to pertinent information. Many single Soldier tasks can be mixed to formulate a realistic dual-task scenario that will occur in battle, demanding a Soldier's attention. However, the fire fight is thought to be the most stressful, highest demand scenario. The effect of shooting under cognitive load has been studied by the U.S. Army Research Laboratory (ARL) in recent years (Scribner & Harper, 2001; Scribner, 2002; Kelley & Scribner, 2003; Kerick, Hatfield, & Allender, 2004). Recently, Scribner, Wiley, and Harper (2005) found that various secondary task displays make a difference in the amount of processing that can be accomplished by a Soldier while shooting. It was found that auditory displays allow the highest hit percentage on enemy targets while visual displays allow more secondary tasks to be accomplished. A trade-off found that a forearm-mounted display (FMD) with an auditory cue served the best at an optimum mix of these performance measures. The auditory cue signaled the presence of a new secondary task on screen, allowing better task-switching behavior between shooting and solving math addition problems. The next logical step in this research was to determine if continued performance would change the outcome of performance measures over time.

1.2 Sleep Deprivation, Circadian Rhythm, and Marksmanship

From the existing data, several studies have examined the effects of various pharmacological substances on shooting performance during a 3-hour sentry task. Johnson and Merullo (1996) found that for 3-hour test sessions, target detection response time deteriorated with time on sentry duty and that vigilance decrements were attenuated by 200 mg of caffeine. For men, marksmanship accuracy was constant over time; for women, marksmanship accuracy deteriorated after 1.5 hours. Johnson and Merullo (1999) found that over a 3-hour sentry duty mission, 200 mg of caffeine reduced friend-or-foe discrimination errors and eliminated the time decrement in target detection speed associated with the time on task. It was also determined that men committed more

friendly fire errors (commission), but women committed more fail-to-engage-enemy target errors (omission).

Going beyond the 3-hour sentry duty task, Haslam (1982) reported that infantry Soldiers shooting in the prone position hit 25% fewer pop-up targets when they were deprived of sleep longer than 48 hours. When Soldiers were deprived of sleep for 90 hours, there was no deterioration in shooting performance on a stationary target with no time constraint; however, performance was reduced 10% for randomly presented targets on a firing range. Additionally, Tharion et al. (1997) found that for 68 SEAL (sea-air-land) trainees tested during "Hell Week," the 72-hour period of sleep deprivation degraded all measures of marksmanship performance. There was a 37.5% increase in targets missed, 38% increase in the distance from the center of mass of the target, 235% increase in shot group dispersion, and 53% increase in sighting time (3.1 s). Tharion also found that 200- and 300-mg doses of caffeine attenuated sighting time significantly over placebo and a lower dose of caffeine (100 mg).

Antal (1975) found that competitive shooters suffered performance decrements when flying long flights that crossed time zones, thus desynchronizing their circadian rhythms. The worst performances were seen during the low points in circadian rhythm: between midnight and 0500 hours.

1.3 Objectives

The present study had a three-fold purpose. It was designed to (a) repeat the conditions of a previous study examining the effects of a secondary task presented in various display modalities (no secondary task workload, auditory display, and two visual displays with an auditory alert cue; (b) examine shooting performance during sleep deprivation in a mix of military-relevant tasks, and (c) examine the possible interaction effects of shooting and performing a secondary task with various displays during various increments of sleep deprivation.

2. Hypotheses

1. The efficiency of the visual system will yield improved Soldier secondary task performance, workload, and stress ratings over the auditory system. (The separation of workload channels should yield higher shooting performance with the auditory system during all sleep deprivation periods.)
2. The FMD with an auditory alert cue will yield improved Soldier secondary task performance, workload, and stress ratings because of more efficient task switching over an auditory display for secondary task during all sleep deprivation periods.
3. Sleep deprivation will yield diminishing primary and secondary task performance and subjective ratings of stress and workload over longer periods of sleep deprivation.

3. Methods

The primary task in this study was a friend-or-foe discrimination shooting task. The secondary task used in this study was a non-loading or subsidiary task comprised of mathematical addition problems. Subjects were instructed to avoid making errors on the primary task (friend-or-foe discrimination shooting task) while performing as many of the secondary task problems as possible, after the primary task was accomplished.

3.1 Friend-or-Foe Shooting Scenario

A friend-or-foe decision was used in this shooting task to provide a more realistic mental burden to the shooting task (Scribner & Harper, 2001; Scribner, 2002). Twelve of 24 pop-up targets were brown "E-type" silhouettes to identify them as friendly, causing a desired "do not shoot" decision (figure 1, left). Black "E-type" silhouette targets were designated as enemy targets, which were to be fired upon (figure 1, right).

The shoot/do-not-shoot task was added because of the ever-increasing probability of Soldiers encountering friendly, neutral, or non-combatants in the fighting environment. The targets were all exposed for a duration of 3 seconds and went down if hit before the 3 seconds expired.

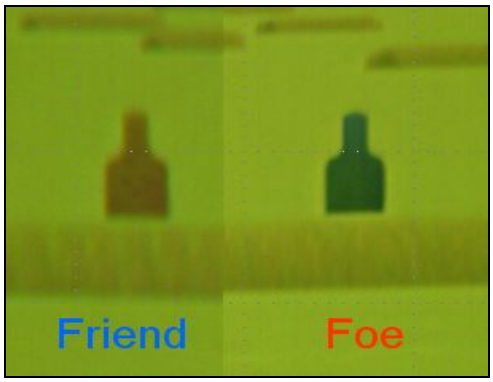

Figure 1. "Friendly" and "enemy" targets.

3.2 Display Modalities

The different modalities of workload presentation were used to compare likely modes of information display for the Soldier. This involves the presentation of information through auditory (via ear buds connected to the FMD), a visual display on the forearm, and a helmet-mounted display (HMD) worn over the non-aiming eye (figure 2). The visual displays had an auditory alert cue to signal the presence of a new math problem in the display in all conditions.

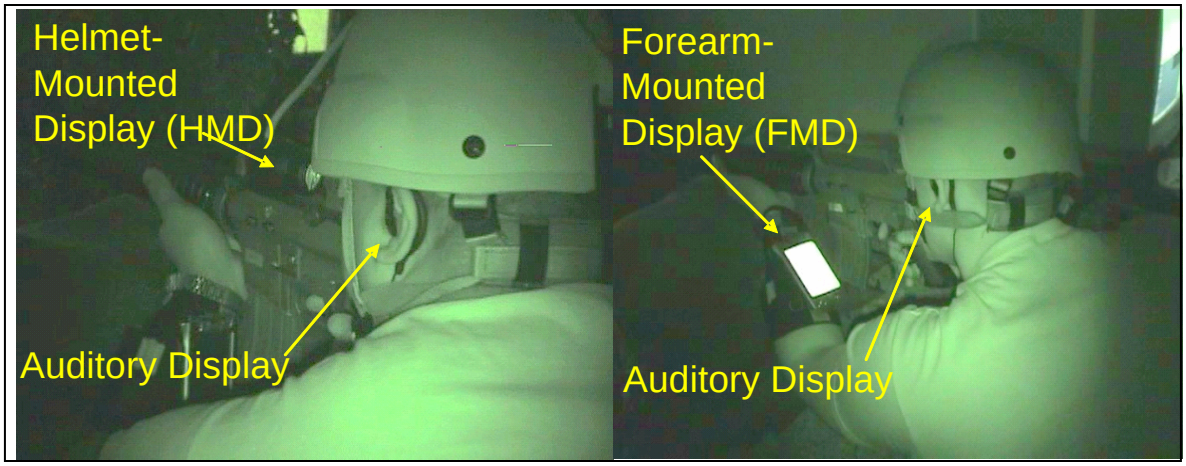

Figure 2. Visual and auditory equipment worn.

3.3 Participants

Participants were 12 male U.S. Army Soldiers, recruited from the 143rd Ordnance Batallion at Aberdeen Proving Ground (APG), Maryland, Edgewood area. All subjects met requirements for 20/30 visual acuity. All subjects were experienced with the M16A2 and had required minimum weapons qualification.

3.4 Apparatus

3.4.1 Volunteer Agreement Affidavit

A volunteer agreement affidavit (VAA) (appendix A) was given to each test participant to review before participating in the study. This form was used as the single VAA for several studies performed simultaneously, which were all aligned under one research protocol number (Burton, 2007). The VAA used describes this study and others. Upon reading the document, test participants were able to ask all questions concerning their participation in the study. After they agreed to participate, they signed the document.

3.4.2 Demographic Questionnaire

A demographic questionnaire (appendix B) was administered to collect age, gender, military occupational specialty (MOS), years in that MOS, and other background information.

3.4.3 Titmus[1] II Vision Testing Device

Subjects were screened for 20/30 both-eye visual acuity far distance with a Titmus II visual testing device.

[1]Titmus is a registered trademark of Titmus Optical.

3.4.4 Dismounted Infantry Survivability and Lethality Test Bed (DISALT)

ARL's Human Research and Engineering Directorate leads the Army's study of shooting performance with small arms systems. The Warrior Performance Research Team of the Dismounted Warrior Branch has a newly acquired small arms shooting simulation facility called the DISALT (figure 3).

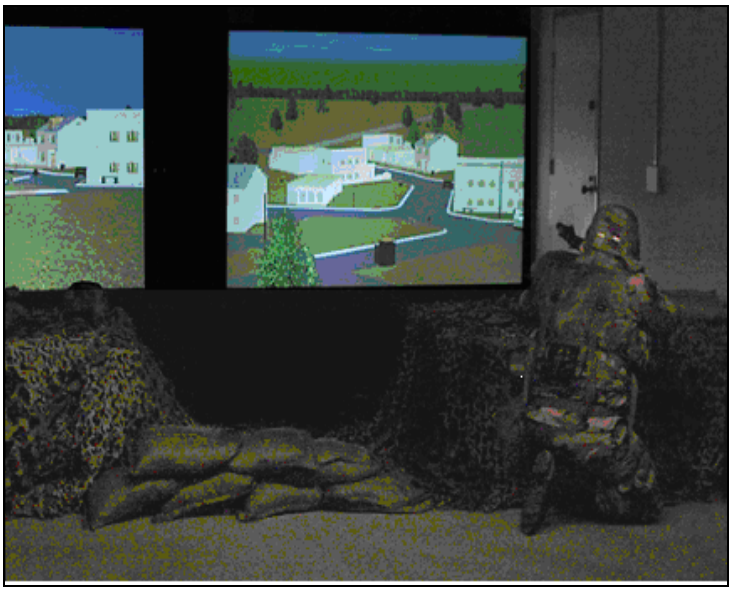

Figure 3. Two-lane DISALT shooting simulator.

The DISALT was originally manufactured to serve as a U.S. Marine Corps marksmanship trainer for ship-borne operations; however, it is highly effective as a research tool for many aspects of scientific research because of its high-fidelity data-capturing capability and flexibility in providing many types of target and three-dimensional environment shooting scenarios. Customized environments for the simulator were created to include the first experimental environment built for research, the simulated outdoor small arms experimental range or "M-Range" as it is called locally at APG (figure 4).

Figure 4. Live and virtual representations of M range.

3.4.5 Mathematical Problem-Solving Task (secondary)

For all modes, the subject had 2.5 seconds to speak the correct answer or it was scored as an error. Twenty problems were presented to each participant per shooting trial. The problems consisted of adding double-digit and single-digit numbers, always requiring a carrying operation. The number of math problems correctly solved was calculated to score this secondary task.

3.4.6 Secondary Task Display

The first condition for secondary task was "none," in which the participant wore all the equipment turned off, with no secondary task required. The visual conditions consisted of an HMD or an FMD. The FMD was a pocket personal computer mounted with Velcro[2] to the inside of the fore-arm so that it could be easily seen in a shooting posture. Both visual display modes were presented with or without an auditory warning cue that signaled the presence of a new math problem on the screen. Finally, an auditory condition was also presented via pre-recorded problems from a computer-generated voice.

3.4.7 Subjective Workload Assessment Technique (SWAT)

SWAT (Reid, Potter, & Bressler, 1988) was used to quantify Soldier workload ratings during various conditions. SWAT has been validated with mathematical processing tasks of various levels for workload assessment. The SWAT form is shown in appendix C. SWAT captures three workload dimensions as well as overall workload:

- Time load is the amount of time pressure that the Soldier experiences in performing the task.
- Mental effort load is the amount of attention and/or concentration required to perform a task.
- Psychological stress load refers to the presence of confusion, frustration, and/or anxiety that hinders the completion of a task.

3.4.8 Weapons and Ammunition

Two demilitarized and electronically altered M16A2 rifles with iron sights that accompany the DISALT were used in this study.

3.5 Design and Analysis

3.5.1 Independent Variables

The variables manipulated in this study were the displays used to present secondary task (math problems) information to the Soldiers:

- Secondary task display type (none, auditory, FMD + Cue, HMD + Cue),

[2]Velcro is a registered trademark of Velcro USA, Inc.

- 6-hour increments of sleep deprivation (from 0 to 30 hours).

3.5.2 Dependent Variables

The data collected consisted of shooting performance (errors or correct judgements of whether to shoot at friendly and enemy targets), enemy hit percentage, first shot reaction time, secondary task performance (math problem completion), subjective workload and stress ratings.

4. Procedure and Methodology

All subjects in this study were exposed to a series of different experiments within a 6-hour period. These 6-hour periods were repeated five times for a total of 30 hours of sleepless activity. Groups of three Soldiers were created to stagger the administration of each phase of activities. Each 6-hour period included the following activities:

An assortment of cognition, workload, fatigue, and sleepiness test batteries was administered to each test participant.

Following this, two 20-minute sessions of playing "Operation Flashpoint[3]," a first-person military game, were used to simulate a mission to clear a village of enemy insurgents, while avoiding contact with civilians in the area. A total of 10 enemy insurgents was present, along with land mines, which were to be avoided while Soldiers traversed the terrain. This was performed in normal noise levels and with battlefield noise levels.

Next, test participants played another first person shooter PC game, Tom Clancy's Rainbow 6[4]: III; Raven Shield, to simulate the use of a remote unmanned aerial vehicle (UAV) to navigate to six different waypoints with a paper map and digital map provided on a personal digital assistant (PDA)-type display. At each waypoint, the participant was shown an image that simulates a view from a UAV and was asked to locate his/her own position on the image. S/he was then asked to identify another location on this same image by moving the mouse to an appropriate location and clicking the mouse to designate the location on the image. Completion of all six waypoints was considered one test condition. After a 5-minute break, participants completed a second test condition in which the only difference between this condition and the previous condition was that cues were presented to help orient the Soldier to the UAV images that were presented. The two test conditions together took approximately 40 minutes to complete.

Following the UAV cue study, test participants proceeded to the DISALT facility in building 459 at APG to take part in the shooting performance portion of the study.

[3]Operation Flashpoint is a registered trademark of Codemasters Software Company Ltd.

[4]Tom Clancy's Rainbow 6 III, Raven Shield, is a registered trademark of Ubisoft.

The shooting simulation was followed by 1-1/2 hours of free time. During this time, recreational activities (X-box games, TV, board games, magazines, etc.) were made available in the participants' waiting area, and the test participants were encouraged to use these items. An experimenter was present in the waiting room and assured that participants did not doze. If a participant fell asleep, the experimenter called his/her name and tapped his/her shoulder gently. If necessary, the participants were assigned an escort to walk or talk with them to assist them in staying awake. Snacks and beverages were also made available throughout the duration of the testing. Breakfast, lunch, and dinner were made available at appropriate times.

4.1 Participant Scenario, Shooting Study

The subjects reported to building 459, third floor simulation facility, to begin study participation. As part of the pre-test procedure, participants were given a VAA, which described the study and possible risks. They were then screened for visual acuity with a Titmus II vision-testing device. If visual criteria were not met, the participants were excused from the study. Demographic data were collected at this time.

The SWAT technique for measuring workload had two parts: scale development and event scoring. In scale development, a card-sorting exercise is conducted, which is designed to determine the subjective conception of workload for each subject within three dimensions: time load, mental load, and psychological stress. Each dimension had three levels associated with it for a total of 27 possible combinations. During the sorting task, a subject sorts 27 cards representing all possible combinations of the SWAT dimensions. By arranging the cards in an order representing which combinations of the dimensions the subject thinks describes the lowest workload to the highest workload combinations, a scale can be created that reflects the way a subject (or a group) perceives the concept of workload. This defines the mathematical model for combining the three elements into a single dimension of subjective mental workload or conjoint analysis.

During event scoring, the subjects rated the experimental conditions using the dimensions of SWAT, one set of ratings for each event. After the events were rated, the workload for each experimental condition was derived. A sample of the event scoring SWAT form is provided in appendix C.

The shooting task consisted of a 24-target pop-up scenario with friendly (brown targets) and enemy (black) E-type silhouette targets. Half of the targets were friendly and half were enemy. Ranges consisted of 75-, 100-, 150-, 200-, 250-, and 300-meter targets.

Target exposure time was 3 seconds with a 2-second inter-target interval which was constant through all trials. Soldiers were in a kneeling supported firing position for all trials. Demilitarized M16A2 rifles outfitted with electronic switches for the firing selector and trigger with iron sights were used for this study.

The secondary task stimuli (math problems) were presented on one of three displays: an FMD (visual) with an auditory alert cue, an HMD (visual) with an auditory alert cue, or aurally. In the

aural mode, each math problem presented consisted of a spoken math problem followed immediately by a brief response cue tone, indicating permission for the test participant to respond. The auditory mode employed ear "buds" that fit into the ear canal. For data verification, experimenters wore ear buds connected to the same device in all conditions so that they could hear the problem being presented and the response. Volume levels were adjustable so that the test participant could hear the spoken messages at a comfortable volume. There was a fourth condition in which no workload was presented during the shooting trial.

For visual modes, the entire math problem was presented on an FMD or HMD for time equal to that required for the spoken math problem in the aural mode. The visual with auditory cue mode was identical to the visual-only mode with the addition of a brief presentation cue tone that indicated that a math problem had been presented on the visual display. In all visual modes, response cue tones were presented to signal the start of the response interval. Ear buds and helmets, with HMD mounted (but flipped up, out of the way when not used), were worn in all trials to maintain similarity in all trials for equipment worn.

All Soldiers were trained by shooting three, 18-target pop-up scenarios, where all targets were fired upon. They then watched one 24-target friend-or-foe pop-up scenario where friendly targets were not to be fired upon. They then practiced three friend-or-foe shooting trials with no workload stimulus. This gave the subjects familiarity with the shoot/do-not-shoot aspect of the experimental trials. A minimum of six targets hit was required in each of the first three trials. All subjects met the training criteria. Following this training, all experimental trials were presented to the Soldiers, which were counter-balanced to minimize learning and order effects. These order tables were configured with a Latin square and used variations of this order for each of six time periods from 0 to 30 hours. Each Soldier was exposed to a series of four shooting trials in each of five 6-hour time periods.

Following each trial, each test participant's cognitive workload was collected with SWAT data forms. Test participants were then fully de-briefed and given a point of contact for individual performance or results of the study.

5. Results

A 4x5 repeated measures analysis of variance (ANOVA) was used to examine the effects of secondary task displays and hours of sleeplessness on all dependent measures. The four levels of display (no workload, auditory, FMD with auditory cue, and HMD with auditory cue) were crossed with five 6-hour time periods of continued sleep deprivation. Tukey's Least Significant Difference (LSD) test was used as a *post hoc* analysis.

The simple effect of hours of sleeplessness had no significant effects for all dependent measures except for SWAT workload ratings, which were $p = .009$. There were many cell comparison differences, as can be seen in figure 10. This curve estimation was not significant, yet nearly so at $p = .076$, R-square = .025, F = 2.321, df1 = 2, df2 = 276 for a cubic function.

There were many significant findings for the simple effect of display type. Shot reaction time ($p = .007$), friendly fire error percentage ($p = .046$), enemy miss error percentage ($p = .032$), percentage of math problems completed ($p = .000$), and SWAT workload ratings ($p = .000$) were all found to be significant. The shot reaction time was lowest for the two visual displays as compared to the no-workload condition. The friendly fire errors were highest for the HMD with cue condition as compared to no workload. The enemy miss error data were significantly higher for the secondary task workload conditions than for the no-workload condition. The percentage of math problems solved was significantly higher for the two visual displays as compared to the auditory display. The SWAT workload ratings were significantly higher for all the workload conditions as compared to no workload.

The Hours of Sleeplessness x Display Type interaction effect was non-significant for all measures except for enemy hit percentage ($p = .026$). The enemy hit percentage varied as a function of sleepless hours and by the display type. The ANOVA data are presented in table 1.

Significant data for the simple effect of display type are presented in figures 5 through 9. Data for the simple effect of hours of sleeplessness are displayed in figure 10. Data for the interaction effect of enemy hit percentage by hours of sleeplessness and display type are presented in figure 11.

A curve-estimation test was applied to the data to determine if a statistically significant effect was present in the enemy hit data. There was a significant quadratic curve equation for these data ($p = .015$, R-square = .030, F = 4.236, df1 = 2, df2 = 277). This curve describes performance increasing until about 18 hours at which point, it declined over the next 12-hours. It is also interesting to note that at peak performance, SWAT workload ratings were at their lowest, showing a potentially strong relationship to the enemy hit data. These workload rating data were nearly the opposite phase of the enemy hit data.

Table 1. ANOVA table of dependent measures.

	Condition	SS	df	MS	F	P
Shot Reaction Time(s)						
	Sleepless Hours	.218	5	.044	1.646	.164
	Error	1.407	53	.027		
	Display Type	.161	3	.054	4.757	**.007**
	Error	.376	33.414	.011		
	Hours x Display	.276	15	.018	1.390	.158
	Error	2.102	159	.013		
Friendly Fire Error (percent)						
	Sleepless Hours	377.836	5	75.567	.301	.910
	Error	13306.771	53	251.071		
	Display Type	1718.662	3	572.887	2.970	**.046**
	Error	6407.674	33.221	192.881		
	Hours x Display	1648.785	15	109.919	.906	.558
	Error	19284.664	159	121.287		
Enemy Miss Error (percent)						
	Sleepless Hours	928.299	5	185.660	1.754	.138
	Error	5609.317	53	105.836		
	Display Type	1080.313	3	360.104	3.319	**.032**
	Error	3617.703	33.339	108.513		
	Hours x Display	947.396	15	63.160	.605	.868
	Error	16605.266	159	104.436		
Math Problems Completed (percent)						
	Sleepless Hours	2044.354	5	408.871	2.124	.077
	Error	10204.188	53	192.532		
	Display Type	265066.285	3	88355.428	90.442	**.000**
	Error	32276.316	33.039	976.929		
	Hours x Display	2116.063	15	141.071	1.310	.202
	Error	17119.563	159	107.670		
Enemy Hits (percent)						
	Sleepless Hours	1821.991	5	364.398	1.740	.142
	Error	11100.463	53	209.443		
	Display Type	795.493	3	265.164	1.777	.170
	Error	4969.917	33.312	149.195		
	Hours x Display	3787.269	15	252.485	1.911	**.026**
	Error	21003.241	159	132.096		
SWAT						
	Sleepless Hours	7579.28	5	1515.856	3.446	**.009**
	Error	23314.715	53	439.9		
	Display Type	84948.962	3	28316.321	38.573	**.000**
	Error	24306.352	33.110	734.098		
	Hours x Display	2866.301	15	191.087	.825	.648
	Error	36810.541	159	231.513		

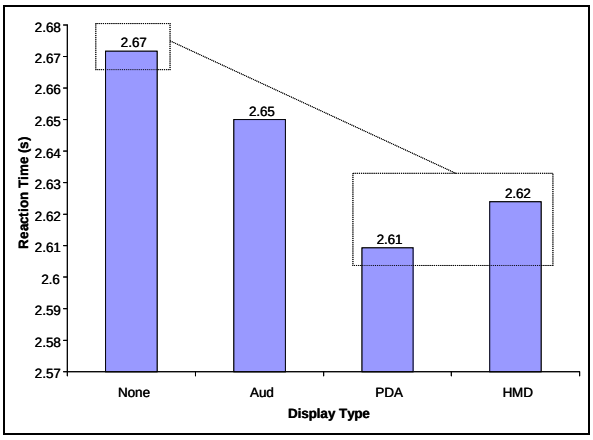

Figure 5. Reaction time(s) by display type.

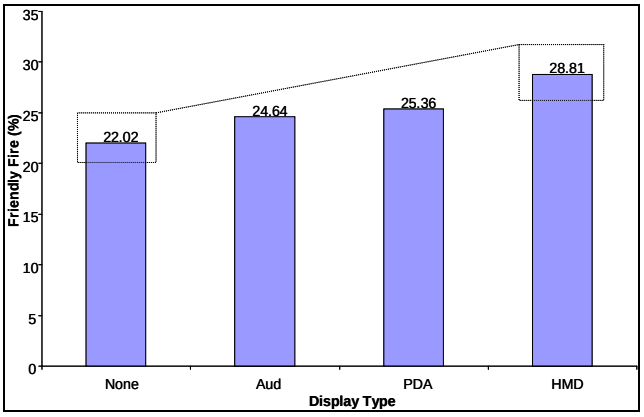

Figure 6. Friendly fire error by display type.

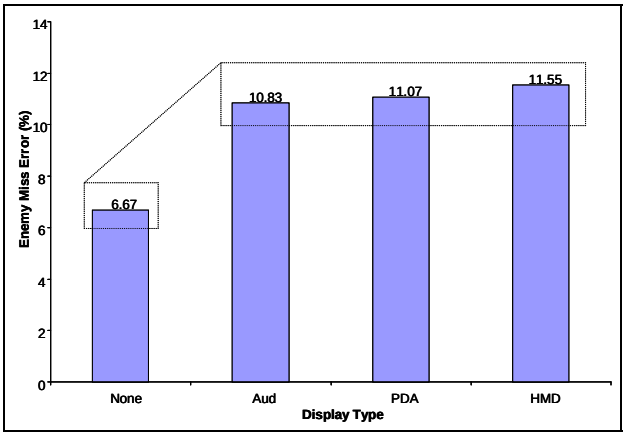

Figure 7. Enemy miss error by display type.

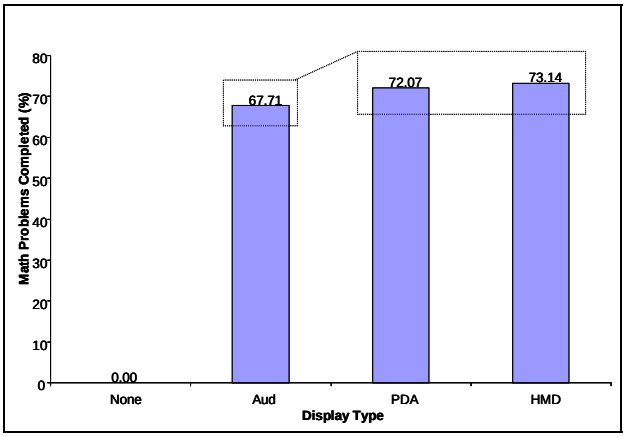

Figure 8. Math problems solved by display type.

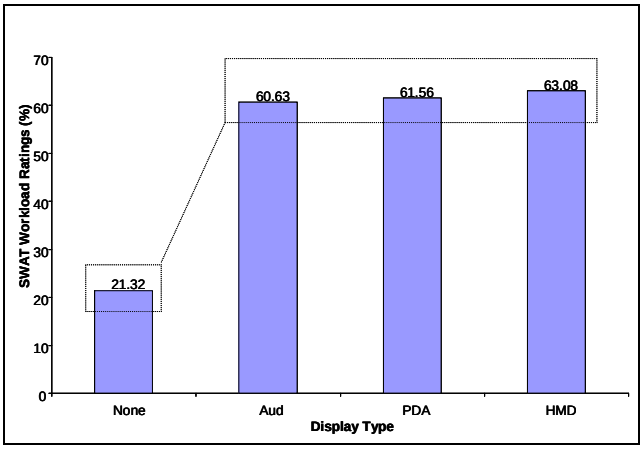

Figure 9. SWAT ratings by display type.

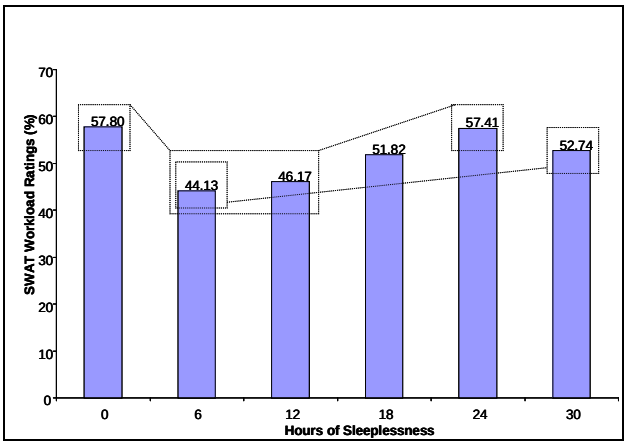

Figure 10. SWAT ratings by sleepless hours.

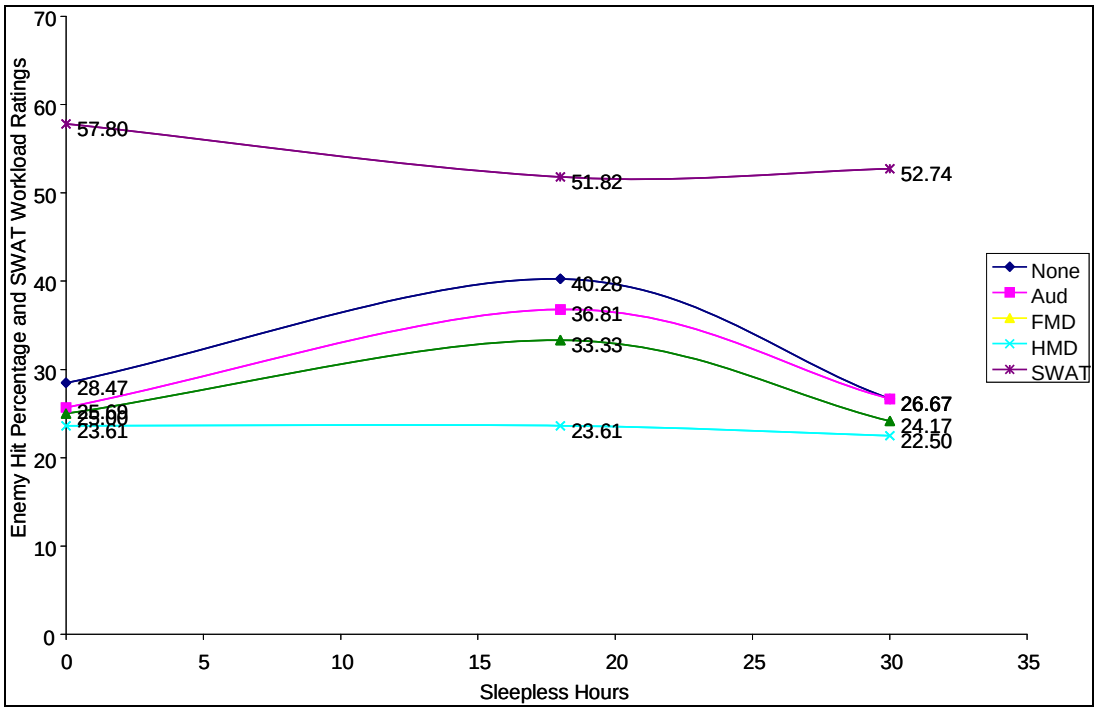

Figure 11. Enemy hit percentage for display type by sleepless hours (SWAT added for comparison).

6. Discussion

The first hypothesis was supported with the math problem completion data which showed that the secondary task performance, or the mean number of math problems correctly solved (percentage), mirrors the Scribner 2005 data, except that the difference in this study was half that of the previous study. The difference in secondary task completion was about 10% between auditory and visual displays in the previous study as compared to about 5% for this study. The auditory mode had a significantly lower number of problems than the two visual modes.

The second hypothesis was not supported with specific data in this study; however, there are some similar data to report. The visual displays (FMD and HMD with auditory alert cues) yielded the lowest reaction times of all the displays used. The cell differences were attributable to the effect of both visual displays as compared to no workload for reaction time. Friendly fire error cell differences showed that error was highest for the HMD and lowest for the no-workload condition (no display), leaving the auditory and FMD as equals for with the lowest friendly fire error under workload. These data support the Scribner data of 2005 for these types of displays. Enemy miss, math problem completion, and SWAT workload rating data were unremarkable since the cells for all displays were essentially equal and only differed from the no-workload condition.

As for the third hypothesis, the SWAT workload data for hours of sleeplessness appear to assume a curved function. The SWAT data, when plotted with the enemy hit percentage chart for hours and display type, have an inverted function in that lower SWAT values are associated with higher performance values. This effect shows that the SWAT is a highly useful tool for assessing workload, which in turn impacts this dual-task performance.

It appears that most of the significant differences were yielded for the simple effect of display type. There was one measure that showed a difference for the simple effect of hours and one measure that showed an interaction effect.

The data for enemy hit percentage were the only interaction effect that was found to be significant. The data are difficult to describe, but when shown for 0, 18, and 30 hours, have quite a clear picture.

The data seem to trend in a fashion that shows the highest hit percentage for the auditory display over visual displays over longer periods of sleeplessness. Additionally, the FMD had the better of the two visual display hit percentages with the HMD having a very flat response rate over hours awake. It can be seen that the performance increases were evident for no workload, auditory, and FMD displays but not for HMD. The HMD possesses some limiting factors that make it the worst choice for dual task work where shooting is involved. The workload data, as evidenced by the SWAT, showed an opposite trend to the enemy hit data. This may imply that when overall workload is lower, a greater enemy hit percentage is achieved. All conditions did seem to merge to low performance at the 30-hour mark. However, even at this point, the auditory display seems to be separated from the two visual displays in performance. In general, it seems to reiterate several points: the HMD is the poorest display for enemy hit performance; the FMD is the best visual display for hit percentage; and auditory presentation of workload still gives the best performance for hit percentage under dual task workload scenarios for as many as 30 sleepless hours.

7. Conclusions

The data have shown some support for auditory displays being superior to visual for primary shooting task performance. The recommended display for the dismounted Soldier would be to wear an auditory display for simple information. If information is more complex, it would be recommended that an FMD with auditory alert cues be worn as the display of choice. This holds true during as many as 30 hours of continuous operations. The HMD has shown itself to be the best display for math problem completion (secondary task) performance; yet, it is the poorest in shooting (primary task performance). The data in this study and the Scribner 2005 data support this notion as well. This also holds true in continuous operations scenarios where the relationship between auditory and visual displays remains unchanged. The data in this study also bring new evidence to light showing a negative relationship between workload ratings and enemy hit

performance. They show that when workload is lessened, that a higher percentage of enemy targets can be hit successfully.

Other measures collected in this study did not seem to be sensitive enough for the time duration of this study. However, this study provides strong supporting data for previous research of the usefulness of secondary task displays during dual task performance regimes.

In future research if this type, it is recommended that the subject pool be screened for shooting performance over and above the “average” Army marksmanship scores. This may provide more sensitivity to the shooting performance measures in future continuous operations research.

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Appendix A. Volunteer Agreement Affidavit

VOLUNTEER AGREEMENT AFFIDAVIT:
ARL-HRED Local Adaptation of DA Form 5303-R. For use of this form, see AR 70-25 or AR 40-38

The proponent for this research is:	**U.S. Army Research Laboratory** **Human Research and Engineering Directorate** **Aberdeen Proving Ground, MD 21005**

Authority:	Privacy Act of 1974, 10 U.S.C. 3013, [Subject to the authority, direction, and control of the Secretary of Defense and subject to the provisions of chapter 6 of this title, the Secretary of the Army is responsible for, and has the authority necessary to conduct, all affairs of the Department of the Army, including the following functions: (4) Equipping (including research and development), 44 USC 3101 [The head of each Federal agency shall make and preserve records containing adequate and proper documentation of the organization, functions, policies, decisions, procedures, and essential transactions of the agency and designed to furnish the information necessary to protect the legal and financial rights of the Government and of persons directly affected by the agency's activities]
Principal purpose:	To document voluntary participation in the Research program.
Routine Uses:	The SSN and home address will be used for identification and locating purposes. Information derived from the project will be used for documentation, adjudication of claims, and mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.
Disclosure:	The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this data collection.

Part A • Volunteer agreement affidavit for subjects in approved Department of Army research projects

Note: Volunteers are authorized medical care for any injury or disease that is the direct result of participating in this project (under the provisions of AR 40-38 and AR 70-25).

Title of Research Project:	The Effect of Visually-Presented Workload Stimuli on Soldier Shooting Performance	
Human Use Protocol Log # Number:	**ARL-20078-06053**	
Principal Investigator:	Pam Burton ARL, HRED Bldg 459, Rm 331B Aberdeen Proving Ground, MD 21005	Phone: 410-278-5983 E-Mail: dscribne@arl.army.mil
Associate Investigator(s)	Frank Morelli ARL, HRED Bldg 459, Rm 238 Aberdeen Proving Ground, MD 21005	Phone: 410-278-5994 E-Mail: pwiley@arl.army.mil Phone: 410-278-5955 E-Mail: bharper@arl.army.mil
Location of Research:	HRED, Bldgs 459, 518, 519, APG, MD 21005	
Dates of Participation:		

Part B • To be completed by the Principal Investigator

Note: Instruction for elements of the informed consent provided as detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.

Purpose of the Research

You are being asked to volunteer in a series of three experiments being conducted in succession. The first experiment will examine the sensitivity of the Army Cognitive Readiness Assessment (ACRA) Battery on cognitive processing when performing a variety of tasks. In addition, while performing the tasks of the first experiment, the Army Research Laboratory, Human Research and Engineering Directorate (HRED) and the University of Central Florida will collect information on the non-auditory effects of noise on your performance as well as heart rate and skin temperature (the tasks are described below). Information gathered from this study will be used in subsequent research endeavors and will be used to assess the impact of short-term stress on cognitive performance. The second study is designed to aid us in understanding how information provided by remote sensors (such as unmanned aerial vehicles) will help you navigate through and understand events happening in your environment. The third study is designed to examine your ability to perform shooting tasks under different levels of workload and while performing decision making tasks.

Procedures

If you agree to participate in this study, you will be asked to sign this Volunteer Agreement Affidavit. You will then complete a brief vision and hearing screening. We will be assessing your visual acuity, color vision, and hearing threshold. Next, you will complete a series of questionnaires. First, you will be given a list of adjectives (known as MAACL-R) and asked to check all the words that describe how you feel right now. Next, you will be asked to complete a team behavior questionnaire followed by a demographics questionnaire. We would like to obtain your ASVAB score; however, this is your choice and you need not feel pressured to provide your score. There is a designated area provided at the bottom of this form if you wish to give permission for us to obtain your ASVAB score.

The total time obligation required by you, from start to finish, including travel, training and testing will be 71 hours. The first day of the study will be a training day and will begin at 0630 and end at 1730 hrs. Testing will begin on day 2; you will be picked up at 1800 and driven to the Aberdeen Proving Ground, Building 459 ARL, HRED. Testing will continue for at least 48 hours of sustained testing followed by 12 hours of rest. Basically, you will be awake for at least 48 hours followed by an extended rest period. As you fatigue, you may experience a decrease in your cognitive abilities, motivation, and mood. However, there are no direct physical or mental risks associated with participating in this study.

Transportation to and from the test site and your duty station will be provided by the ARL. On training day, you will be trained on the cognitive assessment battery (ACRA) and on a first person video game called Raven-Shield. You will also be shown the location of the facilities, the participant waiting room, designated smoking areas and the dining area. You will also be introduced to the experimenters, any of whom will be glad to answer questions. At the end of the training you will be returned to your duty station.

The following day, you will picked-up at your duty station at 1800. Upon arrival, at the ARL, you will be fitted with a heart monitor, which consists of a strap worn comfortably around the chest and a wrist-watch type device. A plastic strip, similar to an ordinary BandAid will be placed at the back of your neck to monitor skin temperature. You will wear the chest strap, wrist

watch, and temperature strip throughout the study. If at any time you feel discomfort from any of these devices, please inform the experimenter and the devices will be adjusted or removed if the discomfort persists.

One part of this study is assessing the ability of the ACRA to predict performance as you become fatigued. For purposes of testing and accountability, you will be divided into groups of three and you will remain with your group throughout the test period. You will begin by completing a series of questionnaires concerning what you're feeling about your current workload, stress, and level of fatigue. The questionnaires should take less than 5 minutes to complete. You will then complete a 15 session of the ACRA, which will be administered to three individuals at a time.

When all three individuals in your group have completed the ACRA, your group will be escorted to the video game stations located in an adjacent building. At the beginning of each video game session, you will again complete the fatigue and stress questionnaires. Upon completion of the questionnaires, each member of your group will begin the video game simultaneously; however, you will be playing as an individual and not a team. The game play will last for 20 minutes and then you will receive a 5 minute break and begin another 20 minute game. You will be wearing headphones during the game over which you will hear the sounds inherent to the game (footsteps, gunfire, breathing sounds, etc). During one of the 20 minute game play periods you will hear only the game-generated sounds coming through the headphones. During the other 20 minute game play, in addition to the sounds produced by the game, you will hear the background noises of battle (artillery shelling, mortar fire, grenades, etc.) as projected from speakers in the room. The sounds will be loud, but will be maintained below the maximum safety levels and allowable daily levels determined by the OSHA and the U.S. Army Standard (DA PAM-40-501R with addenda). The order in which the battle noises and games noises are presented will vary. Sometimes you will play the 20 minute battlefield noise session first and sometimes the game noise session will be first. Following completion of the video game, you will once again complete the MAACL-R and a selection of the fatigue and workload questionnaires. Once you have completed the questionnaires, you will be escorted back to building 459 where you will be asked to perform a computer-based simulation referred to as G8.

You will then be escorted to the G8 Remote Sensor Study room. The purpose of this task is to evaluate the ability of Soldiers to understand and use information provided from remote sensors. We will evaluate the effect of sleep deprivation on the effectiveness of the remote sensor information using two different cuing conditions. During the task, you will be sitting in front of a large screen. On the large screen you will navigate through an environment created using a first-person shooter computer game. You will navigate to six different waypoints using a paper map and digital map provided on a PDA-type display. At each waypoint you will be shown an image that simulates a view from an Unmanned Aerial Vehicle (UAV) and asked to locate your own position on the image. You will then be asked to identify another location on this same image. You will answer each question by moving the mouse to the appropriate location and clicking the mouse to designate the location on the image. After you have navigated to all eight waypoints and answered the questions, you will have completed one condition. You will then complete three fatigue and stress questionnaires. You will be given a five minute break and then you will complete a second trial. These trials will be conducted in exactly the same way and the only difference between the two trials will be the cues that will be presented to help orient you to the UAV images that are presented. After the second trial, you will again complete the fatigue and stress questionnaires. The two trials together with the questionnaires will take approximately 40 minutes to complete.

When finished with the G8 test session, you will be escorted to the HRED shooting simulator. You will be firing a de-milled M16A2 rifle at virtual targets, which will consists of friend and foe targets. You will shoot a total of 40, 24-target pop-up scenarios using friend and foe targets while adding simple numbers together that will either be presented on a visual display that you will be wearing on your forearm or through headphones. This shooting task along with the questionnaires will required a total of 30 minutes to complete.

Prior to shooting, you will again be asked to complete fatigue and workload questionnaires.

Once you have completed the shooting simulation, you will have 1 ½ hours of free time. During this time you will be escorted to the participant waiting area or the dining area. While in the participant waiting room (during your free time), you will not be permitted to sleep; however, Xbox games, playing cards, coffee, etc. will be available to assist you in staying awake. There will be an experimenter present in the participant room. If you do begin to doze off, the experimenter will call your name and gently tap your shoulder. The experimenter will assist you in staying awake by talking to you or providing an escort to walk with you. At the end of your 1 ½ hour break, you will repeat the same sequence of events as described above. You will repeat this entire sequence (ACRA/Raven-Shield/G8/Shoot/Break) a total of eight times.

Breakfast, lunch, and dinner will be provided and you will be given ample time to eat. In addition, coffee, soda, and snacks will be available throughout the study. All food, drink, caffeinated beverages, and nicotine intake must be recorded throughout the study. You will receive a checklist for keeping track of this. This checklist will be monitored by the experimenter to ensure that you have consumed food at least every four hours and had a drink at least every two hours.

Please keep in mind that an escort is required at all times. This is not only for your own safety, but we are located in a security area and wandering around without an escort is a security violation. If you need to use the facilities or attend to personal hygiene, ARL personnel will be available to escort you to the nearest restroom. Smoking is

permitted in designated areas only. If you wish to take a smoke break, inform any one of the experimenters and an escort will be provided. On training day, you will be briefed as to the location of smoking areas, availability of snacks and dining, escort procedures, etc. The experimenters will keep track of where you go next and what you will be doing next, however, a test schedule will be posted in the participant waiting room and at each of the test stations in which you can track your own personal schedule of events.

During the entire training and test periods, no telephone calls (incomings or outgoing) will be permitted. Please do not bring cell phones with you. Cell phones with video/camera capabilities are strictly prohibited in the security area in which the training and testing will occur and you will not need them. Emergency contact may be made at any time through Pam Burton at 410-278-5972. Do not hesitate to ask questions or voice concerns. If at any time you feel ill or feel that you need medical attention, please tell one of the experimenters immediately. APG EMTs will be alerted as to the nature of this study and will be available should you need medical attention.
At the end of the experiment, the heart monitor, wrist-watch, and temperature strip will be removed by one of the experimenters. You will then be escorted to Bldg 519 where you will be provided with 12 hours of uninterrupted rest. Cots, pillows, and blankets will be provided and an experimenter will be present during this time. If you need to use the facilities, an escort will be provided. At the end of the 12 hour rest period, you will be transported by the ARL back to your duty station.

Benefits

The ability to assess the cognitive readiness of the warfighter is critical to mission success. The present study will demonstrate the capabilities of a field-usable assessment method that is designed to identify changes in the warfighter's cognitive state due to a typical stressor, notably, fatigue. As a participant, you will receive the personal satisfaction of providing valuable information to Army cognitive sciences research. As a research institution, the ARL will obtain beneficial knowledge concerning the effectiveness of computer-displayed information while under moderate levels of arousal.

Risks

There are no direct physical or mental risks associated with participating in this study beyond the risks of playing a PC-based video game. The risks that may be encountered during this study are typical of the everyday risks encountered by Soldiers; however, as you fatigue, you may experience a decrease in your cognitive abilities, motivation, mood, and slowed reactions to the test stimuli. In spite of these feelings, there are no direct physical or mental risks associated with participating in this study.

Confidentiality

All data and information, including video data obtained about you will be considered privileged and held in confidence. All data will be stored on a secured computer system. Photographic or video images of you taken during this data collection will not be identified with any of your personal information (name, rank, or status). All questionnaires administered will be recorded using a volunteer identifier code and the Principal Investigator will keep your assigned volunteer identifier code in a locked cabinet. If any identifying information appears on the questionnaires (such as name, social security number, birth date, etc.), the investigators will delete the identifying information and replace it with a neutral code number. However, complete confidentiality cannot be promised, particularly if you are a military service member, because information bearing on your health may be required to be reported to appropriate medical or command authorities. In addition, applicable regulations note the possibility that the U.S. Army Medical Research and Materiel Command (MRMC-RCQ) officials may inspect the records.

Participation in this study is strictly voluntary. Participants, who choose not to participate, or later wish to withdraw from any portion of it, may do so without penalty. Military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to participate as human participants. No administrative sanctions can be taken against military or civilian personnel for choosing not to participate in this study.

Disposition of Volunteer Agreement Affidavit

The Principal Investigator will retain the original signed Volunteer Agreement Affidavit and forward a photocopy of it to the Chair of the Human Use Committee after the data collection. The Principal Investigator will provide a copy of the signed and initialed Affidavit to you.

Contacts for Additional Assistance

During the study, your POC contact for emergency information will be Pam Burton, 410-278-5972. If you have questions concerning your rights on research-related injury, or if you have any complaints about your treatment while participating in this research, you can contact:

Chair, Human Use Committee
U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425
(410)-278-6237 (DSN)298-6237

OR

Office of the Chief Counsel
U.S. Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1197
(301) 394-1070 or (DSN) 290-1070

Obtaining of ASVAB Scores

IF YOU ARE AN ACTIVE DUTY ENLISTED MILITARY VOLUNTEER, we would like to obtain your Armed Services Vocational Aptitude Battery (ASVAB) scores for potential data analysis. The ASVAB scores would be used strictly for research purposes. The results of any such analyses would be presented for the group of participants as a whole; and no names will be used. With your permission, we will obtain these scores by sending a copy of this signed consent form along with your Social Security Number to the Defense Manpower Data Center (DMDC) in Seaside, CA where ASVAB scores may be obtained from their databases in Arlington, VA or Seaside, CA. If you do not wish your ASVAB scores to be released to the principal investigator, you will still be allowed to participate in the research.

If you would like to participate in this research, please sign one of the following statements, and then complete the information requested at the end of this form:

I **DO AUTHORIZE** you to obtain my ASVAB scores. _____
(Your Signature)

I **DO NOT AUTHORIZE** you to obtain my ASVAB scores. _____

I do hereby volunteer to participate in the research project described in this document. I have full capacity to consent and have attained my 18th birthday. The implications of my voluntary participation, duration, and purpose of the research project, the methods and means by which it is to be conducted, and the inconveniences and hazards that may reasonably be expected have been explained to me. I have been given an opportunity to ask questions concerning this research project. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or project related injury, I may contact the **ARL HRED Human Use Committee Chairperson at the Army Research Laboratory, APG, MD, 21005-5425 or by telephone at (410) 278-6237 or DSN 298-6237.** I understand that any published data will not reveal my identity. If I choose not to participate, or later wish to withdraw from any portion of it, I may do so without penalty.

Printed Name of Volunteer (First, MI., Last)	
Social Security Number (SSN)	***Permanent Address of Volunteer***
Date of Birth (Month, Day, Year)	
Today's Date (Month, Day, Year)	***Signature of Volunteer***
Signature of Administrator	

Appendix B. Demographic Data Form

DEMOGRAPHICS AND EXPERIENCE QUESTIONNAIRE

Subject Number _____

Age_____ Height ___ ft ___ in Weight _____lbs

Rank_____ Date entered military (month)_____ (year)_____

Primary MOS_____ Secondary MOS_____

1. When was the last time you qualified with the M16A2 rifle?

_____ Month _____ Year

2. What is your current level of qualification as a rifleman based on the Army's or Marine's standard?

____expert ____sharpshooter ____marksman

3. Do you usually fire a rifle ____left handed or ____right handed? (Check one)

4. Do you use your ____left eye or ____right eye to aim a weapon?

5. Do you wear glasses or contact lenses when you shoot? ___ Yes ___ No (Check one)

6. Do you play video games or computer games?

____Yes ____No

7. How well do you play video games?
____Poor ____Below Average ____Average ____Above Average ____Excellent

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Appendix C. SWAT Event Rating Form

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

SUBJECT ID_____ TASK ID_____

(Mark an X in one choice for each of the three areas below that best describes what you believe the task workload to be.)

TIME LOAD

1	Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
2	Occasionally have spare time. Interruptions or overlap among activities occur frequently.
3	Almost never have spare time. Interruptions or overlap among activities are frequent, or occur all the time.

MENTAL EFFORT

1	Very little conscious mental effort or concentration required. Activity is almost automatic requiring little or no attention.
2	Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
3	Extensive mental effort or concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS

1	Little consusion, frustration or anxiety exists and can be easily accommodated.
2	Moderate stress due to confusion frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3	High to very intense stress due to confusion frustration or anxiety. High to extreme determination and self-control required.

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BLDG 4506 (DCD) RM 107
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S MIDDLEBROOKS
91012 STATION AVE ROOM 348
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BATTLE CMD BATTLE LAB
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