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EXAMINATION OF THE EFFECT OF NIGHT ILLUMINATION DEVICES ON TARGET ENGAGEMENT ACCURACY

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Abstract

The main aim of this field trial was to assess the capabilities of illumination systems during static and moving (dynamic) target engagement from 35m to 300m ranges using live ammunition (on the Malone 18 range). During night conditions, the investigation of target engagement capabilities for the following illumination systems was carried out with biocular AN/PVS-7D night vision goggles (NVG's) (broad beam): the Visible Light Illuminator (VLI) Tactical Flashlight (pinpoint), the AN/PEQ-2A Illuminator, and the AN/PAQ-4C Laser Pointer.

Soldiers using the AN/PAQ-4C Laser Pointer and AN/PEQ-2A illuminator scored significantly more hits for short-range (less than 100m) target engagements than with the VLI Tactical Flashlight. Conversely, there were no significant differences among the three illuminators for long-range target engagements. This indicates that any of the three types of illumination improved soldiers' long-range (100+ m) target shooting performance on the Malone 18 range.

Overall, soldiers using the AN/PAQ-4C Laser Pointer and AN/PEQ 2A Illuminator scored significantly more hits against static targets than when using the VLI Tactical Flashlight. However, there were no significant differences observed among the three illumination conditions against moving targets, suggesting that none of the systems tested in this study improved the soldiers' detection or engagement of moving targets on the range more than the others.

The AN/PEQ-2A Illuminator had a significantly better acceptability rating over the VLI Tactical Flashlight for functionality, task, vision/optics, and overall open range criteria as well as a significantly better acceptability rating over the AN/PAQ-4C Laser Pointer for vision/optics criteria. This indicates that the AN/PEQ-2A illuminator was more acceptable overall to the soldiers than both the VLI Tactical Flashlight and the AN/PAQ-4C Laser Pointer.

Résumé

L'essai sur le terrain avait comme premier objectif d'évaluer les capacités des systèmes d'illumination (lunettes de vision nocturne AN/PVS-7D, torche tactique VLI [illuminateur à lumière visible], illuminateur AN/PEQ-2A et pointeur laser AN/PAQ-4C) lors de l'engagement de cibles statiques et mobiles (dynamiques) au moyen de munitions chargées (au champ de tir 10 [Malone]).

Les soldats munis du pointeur laser AN/PAQ-4C et de l'illuminateur AN/PEQ-2A ont atteint la cible sensiblement plus souvent pour des engagements sur de courtes distances que ceux qui utilisaient la torche tactique VLI. Par contre, on n'a pas noté de différences sensibles entre les trois illuminateurs pour les engagements de cibles sur de longues distances, ce qui indique que n'importe lequel des trois types d'illumination améliorait le tir des soldats sur de longues distances (100 m et plus) au champ de tir 18 (Malone).

Dans l'ensemble, les soldats munis du pointeur laser AN/PAQ-4C et de l'illuminateur AN/PEQ 2A ont atteint les cibles statiques sensiblement plus souvent que ceux qui utilisaient la torche tactique VLI. Toutefois, on n'a pas constaté de différences sensibles entre les trois conditions d'illumination pour les cibles mobiles, ce qui suggère qu'aucun des systèmes étudiés ici n'améliorait plus qu'un autre la détection et l'engagement des cibles mobiles par les soldats au champ de tir.

Du point de vue de l'acceptabilité, l'illuminateur AN/PEQ-2A s'est avéré sensiblement supérieur à la torche tactique VLI selon les critères de fonctionnalité, de tâche et de vision/optique et l'ensemble des critères applicables au champ de tir, et sensiblement supérieur au pointeur laser AN/PAQ-4C selon les critères de vision/optique. Cela indique que l'illuminateur AN/PEQ-2A était dans l'ensemble plus acceptable pour les soldats que la torche tactique VLI et le pointeur laser AN/PAQ-4C

Executive Summary

A two-day field trial was conducted at Fort Benning, Georgia on 29 March and 10 April of 2002. Sixteen volunteer regular force infantry soldiers completed a standardized marksmanship test while using different illumination devices at night in a repeated measures design. Human factors (HF) tests included assessment of rifle firing performance, visual acuity, contrast sensitivity, and an Exit Questionnaire. Data collection included questionnaires, focus groups, performance measures, and HF observer assessments.

The main aim of this field trial was to assess the capabilities of illumination systems during static and moving (dynamic) target engagement from 35m to 300m ranges using live ammunition (on the Malone 18 range). During night conditions, the investigation of target engagement capabilities for the following illumination systems was carried out with biocular AN/PVS-7D night vision goggles (NVG's) (broad beam): the Visible Light Illuminator (VLI) Tactical Flashlight (pinpoint), the AN/PEQ-2A Illuminator, and the AN/PAQ-4C Laser Pointer.

Soldiers using the AN/PAQ-4C Laser Pointer and AN/PEQ-2A illuminator scored significantly more hits for short-range (less than 100m) target engagements than with the VLI Tactical Flashlight. This indicates that both the AN/PAQ-4C Laser Pointer and AN/PEQ-2A Illuminator out-performed the VLI Tactical Flashlight for short-range (less than 100m) target engagements on the Malone 18 range. Conversely, there were no significant differences among the three illuminators for long-range target engagements. This indicates that any of the three types of illumination improved soldiers' long-range (100+ m) target shooting performance on the Malone 18 range.

Overall, soldiers using the AN/PAQ-4C Laser Pointer and AN/PEQ 2A Illuminator scored significantly more hits against static targets than when using the VLI Tactical Flashlight. This indicates that both the AN/PAQ-4C Laser Pointer and the AN/PEQ-2A Illuminator did improve the soldiers' detection and engagement of static targets on the range. However, there were no significant differences observed among the three illumination conditions against moving targets, suggesting that none of the systems tested in this study improved the soldiers' detection or engagement of moving targets on the range more than the others.

The AN/PEQ-2A Illuminator had a significantly better acceptability rating over the VLI Tactical Flashlight for functionality, task, vision/optics, and overall open range criteria. Furthermore, the AN/PEQ-2A Illuminator had a significantly better acceptability rating over the AN/PAQ-4C Laser Pointer for vision/optics criteria. This indicates that the AN/PEQ-2A illuminator was more acceptable overall to the soldiers than both the VLI Tactical Flashlight and the AN/PAQ-4C Laser Pointer.

Based on the results of this trial, further areas for research and investigation were recommended.

Sommaire

Une étude sur le terrain de deux jours a été menée à Fort Benning, en Géorgie, entre le 29 mars et le 10 avril 2002. Seize soldats d'infanterie de la Force régulière ont été soumis à titre volontaire à un test normalisé d'adresse au tir et ont utilisé, pour ce faire, différents dispositifs d'illumination la nuit selon un protocole de mesures répétées. L'évaluation ergonomique a porté sur les performances de tir au fusil, l'acuité visuelle et la sensibilité aux contrastes, et comportait un questionnaire de sortie. La collecte des données s'est effectuée à l'aide de questionnaires, de groupes de discussion, de mesures de rendement et d'évaluations ergonomiques par des observateurs.

L'essai sur le terrain avait comme premier objectif d'évaluer les capacités des systèmes d'illumination lors de l'engagement de cibles statiques et mobiles (dynamiques) sur des distances allant de 35 à 300 m au moyen de munitions chargées (au champ de tir 18 [Malone]). Pour les conditions de nuit, l'examen des capacités d'engagement de cibles a été effectué à l'aide de lunettes de vision nocturne (LVN) bi-oculaires AN/PVS-7D (faisceau large) pour les systèmes d'illumination suivants : torche tactique VLI (illuminateur à lumière visible) (repérage précis), illuminateur AN/PEQ-2A et pointeur laser AN/PAQ-4C.

Les soldats munis du pointeur laser AN/PAQ-4C et de l'illuminateur AN/PEQ-2A ont atteint la cible sensiblement plus souvent pour des engagements sur de courtes distances (moins de 100 m) que ceux qui utilisaient la torche tactique VLI. Cela indique que le pointeur laser AN/PAQ-4C et l'illuminateur AN/PEQ-2A étaient tous deux supérieurs à la torche tactique VLI pour les engagements sur de courtes distances (moins de 100 m) au champ de tir 18 (Malone). Par contre, on n'a pas noté de différences sensibles entre les trois illuminateurs pour les engagements de cibles sur de longues distances, ce qui indique que n'importe lequel des trois types d'illumination améliorait le tir des soldats sur de longues distances (100 m et plus) au champ de tir 18 (Malone).

Dans l'ensemble, les soldats munis du pointeur laser AN/PAQ-4C et de l'illuminateur AN/PEQ 2A ont atteint les cibles statiques sensiblement plus souvent que ceux qui utilisaient la torche tactique VLI. Cela indique que le pointeur laser AN/PAQ-4C et l'illuminateur AN/PEQ-2A amélioraient tous deux la détection et l'engagement des cibles statiques par les soldats au champ de tir. Toutefois, on n'a pas constaté de différences sensibles entre les trois conditions d'illumination pour les cibles mobiles, ce qui suggère qu'aucun des systèmes étudiés ici n'améliorait plus qu'un autre la détection et l'engagement des cibles mobiles par les soldats au champ de tir.

Du point de vue de l'acceptabilité, l'illuminateur AN/PEQ-2A s'est avéré sensiblement supérieur à la torche tactique VLI selon les critères de fonctionnalité, de tâche et de vision/optique et l'ensemble des critères applicables au champ de tir, et sensiblement supérieur au pointeur laser AN/PAQ-4C selon les critères de vision/optique. Cela indique que l'illuminateur AN/PEQ-2A était dans l'ensemble plus acceptable pour les soldats que la torche tactique VLI et le pointeur laser AN/PAQ-4C.

D'après les résultats de cet essai, nous recommandons une étude plus approfondie et des recherches plus poussées.

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1. Background

Night vision goggles (NVG's) vary according to optical design and image presentation. Optical designs include opaque (Type I) and transparent (Type II) goggles. Type I goggles are usually composed of direct optics and the user views the intensified image directly on a phosphorus screen. Type II goggles are composed of folded optics and use a combiner lens to superimpose the intensified image over the natural one.

NVG's can also be categorized according to the image presented to the eye. There are three divisions according to that classification: monocular, biocular, and binocular. The monocular system feeds one intensified image to one eye, the biocular system feeds the same intensified image to both eyes, and the binocular system feeds separate intensified images to each eye. The monocular system has an objective lens assembly, an image intensifier tube, and a housing assembly. Although the user of a monocular NVG would see a reduced field of view (versus the single eye normal field of view), the image is intensified. The other eye is unaided. The biocular system has an objective lens assembly, an image intensifier tube, a housing assembly, and two eyepieces. Finally, the binocular system uses two objective lens assemblies, two image intensifier tubes, and a binocular housing assembly.

While visual perception research and field studies have identified a number of advantages and disadvantages with monocular, biocular, and binocular NVG's (References A-G), very few controlled studies on dismounted soldier target engagement performance with these devices can be found. Thus, while NVG's are known to enhance foot travel and vehicle operation at night, their effects on shooting performance are not as well understood. Moreover, due to the sensitive nature of the subject, reported studies on target engagement performance with NVG's are not readily available. Therefore, the SIREQ-TD project has initiated a series of scientific investigations to characterize soldier performance with various NVG systems. The scientific investigations completed to date include a preliminary bush-lane trial (Reference H), a conventional gallery range trial (Reference I), an urban lane trial (Reference J), and a secondary bush-lane trial (Reference K).

During the preliminary bush-lane trial (Reference H), the use of NVG's and laser aiming devices were shown to improve night target engagement performance overall, but differences among the NVG's were not significant. This may have been due to the short target engagement distances and the fact that there may have been some unacceptable target detection cueing. In the secondary bush-lane trial (Reference K), longer target engagement distances were used. However, due to equipment failures, target engagement accuracy was not determined and thermal sights were not tested. This trial did show that the use of NVG's with laser aiming devices improved target detection overall.

There are a number of new sighting systems that support close combat rifle engagements; these include aim point sights and laser sights. These devices are marketed as greatly improving day and night shooting performance. Isolated studies and field research have identified a number of advantages and disadvantages with rifle sighting systems. Whilst not exhaustive, the effectiveness of rifle sighting systems can be examined in terms of precision accuracy, speed of target acquisition and engagement, attention narrowing, ease of adjustment, and durability. While open or iron sights are very durable and hold their aim, they are difficult to aim quickly

and cannot deliver precision accuracy. Conversely, optical sights are more fragile, more difficult to aim quickly, and cause attention narrowing. They do, however, offer precision accuracy. Laser sights are affected by environmental factors and are limited by eye-safe laser safety considerations. The latest optical technology in rifle aiming systems is the reflex sight or red dot aiming sight. These sights are advertised as improving day and night rapid target engagement performance. A number of the conventional sighting devices were examined in an Urban Lane trial (Reference J), but the target engagement distances were particularly low. Thus, the results of the sighting system performances in the Urban Lane experiment may not be applicable to general close combat engagement performance.

2. Aim

The aim of this field trial was to assess the capabilities of tactical illuminator systems during static and moving target engagement using live ammunition. This experiment was part of the SIREQ-TD program's investigation efforts in the area of weapon engagement systems. Target ranges varied from 35m to 300m.

The goal of this trial was to quantify performance using three night vision systems with different types of illumination during target engagement scenarios at night:

- biocular AN/PVS-7D NVG with VLI Tactical Flashlight (broad beam);
- biocular AN/PVS-7D NVG with AN/AN/PEQ-2A Illuminator (pinpoint); and
- biocular AN/PVS-7D NVG with AN/PAQ-4C Laser Pointer.

3. Method

3.1 Overview

The following description provides a general overview of the trial method. Further details are provided in subsequent sections.

A two-night field trial was undertaken at Fort Benning, Georgia on 29 March and 10 April, 2002. Sixteen volunteer regular force infantry soldiers were required to complete a standardized marksmanship test while using different illumination devices in a repeated measures design. Section 3.2 describes each of the systems under investigation. During each test, the presentation of conditions was controlled to minimize order effects among participants. Human factors (HF) tests included assessment of rifle firing performance, visual acuity, contrast sensitivity, and an Exit Questionnaire. Data collection included questionnaires, focus groups, performance measures, and HF observer assessments.

3.2 Vision and Illumination Systems

3.2.1 Biocular AN/PVS-7D Night Vision Goggles (NVG)

The biocular AN/PVS-7D is a lightweight, high performance, passive, third generation image intensifier system (see Figure 1). The biocular AN/PVS-7D is either worn on the head as a goggle system or attached to the soldier's helmet. The goggle assembly is a head-mounted, self-contained night vision system containing one biocular unit consisting of an objective lens assembly, an image intensifier tube, a housing assembly, and a binocular eyepiece assembly. The housing is mounted to a face mask assembly which is held by head straps to the user's head. The assembly incorporates an infrared (IR) light source, which provides illumination to permit close-in-viewing. Features include automatic brightness control, bright source protection, low battery indicator, and high-resolution unity F1.2 lens.

Figure 1: Biocular AN/PVS-7D

The biocular AN/PVS-7D has the following specifications:

Magnification Power	1 X
Intensifier Tube	Gen. III
System Gain	3000 fL/fL
Field of View	40 degrees
Depth of field	20 cm to infinity
Interocular Adjustment	-6D to +2D
Power Source	2 AA
Weight	680 grams

3.2.2 AN/PAQ-4C IR Laser

The AN/PAQ-4C is an infrared aiming light that attaches to the C7A1 rifle for night target engagement (see Figure 2). When the system is activated, it sends a steady infrared beam, invisible to the naked eye, along the C7A1's line of fire designating the point of impact on the target. The system utilizes a Class I laser (Helium-Neon) to generate the aiming point. The system marks targets out to a maximum range of 200-300 meters depending on the ambient light available. The system weighs 125 grams and is powered by two standard AA batteries.

Figure 2: AN/PAQ-4C

The AN/PAQ-4C has the following specifications:

Wavelength	830 nanometers (nm)
Power Output	0.7 milliwatts (mW)
Range in Meters	1000
Beam Width	0.3 milliradian (mR)
Beam Modulation	Steady
Battery	(2) AA
Weight	125 grams

3.2.3 AN/PEQ-2A IR Illuminator

The AN/PEQ-2A is a dual laser system that allows either pinpoint aiming or broad beam nighttime target illumination (see Figure 3). The AN/PEQ-2A offers a selection of laser, infrared, or infrared/visible light illumination sources. Once mounted on a weapon, the lasers can be easily and individually bore sighted using the independent azimuth and elevation adjustments. The unit is waterproof to 20 meters, and, under ideal conditions, the range of the Laser Pointer exceeds 16 kilometers. The system weighs 210 grams and is powered by two standard AA batteries.

Figure 3: AN/PEQ-2A

The AN/AN/PEQ-2A has the following specifications:

Aiming Light	
Wavelength	830 nanometers (nm)
Power Output	25 milliwatts (mW)
Range in Meters	>16000
Beam Width (Divergence)	0.3 milliradian (mR)
Beam Modulation	Steady
Pointer/Illuminator	
Wavelength	830 nanometers (nm)
Power Output	30 milliwatts (mW)
Range in Meters	>16000
Spot Beam Width (Divergence)	0.3 milliradian (mR)
Flood Beam Width (Divergence)	>10 degrees
Beam Modulation	Steady
Battery	(2) AA
Weight	210 grams

3.2.4 Visible Light Illuminator (VLI)

The Visible Light illuminator (VLI), or Tactical Flashlight, uses broad beam target illumination that attaches to the C7A1 rifle for nighttime target engagement (see Figure 4). It can be handheld

or mounted to a weapon for operation. The unit is waterproof to 20 meters, and, under ideal conditions, the range of the illumination exceeds 100 meters. The system weighs 7.19 ounces and is powered by either three lithium battery or six standard AA batteries.

Figure 4: Visible light illuminator (VLI)

The VLI Tactical Flashlight has the following specifications:

Pointer/Illuminator	
Power Output	200+ lumens (lithium batteries) 150+ lumens (alkaline batteries)
Range in Meters	>100 m
Weight	7.19 oz (without batteries)
Battery	(6) AA or (3) DL123A

3.3 Trial Conditions

The field trial included 22 test variables; one target presentation order variable, twelve target distance variables (35m, 50m, 60m, 75m, 100m, 125m, 150m, 175m, 185m, 200m, 250m and 300m), two lanes (odd and even), two target conditions (static or moving), three illumination systems (AN/PAQ-4C, AN/PEQ-2A, and VLI Tactical Flashlight), and two night shooting conditions (March 29 and April 10). For this reason, the trial was divided into two data collection blocks (see Table 1) and a complete repeated measures protocol ($n = 16$) was conducted.

The first data collection block involved developing the baseline performance of the AN/PVS-7D with the AN/PAQ-4C Laser Pointer, the AN/AN/PEQ-2A Illuminator, and VLI Tactical Flashlight. Sixteen soldiers engaged targets from 35 to 300 metres with each of these systems. Targets were presented in a random order. Each serial included seven static targets (six presented twice and one presented three times) and five moving targets (each presented twice), for a total of 25 targets per serial.

Table 1: Data collection blocks

Data Block	Test Block	System Configurations	Subjects
1	Night	AN/PVS-7D w VLI Tactical Flashlight AN/PVS-7D w AN/AN/PEQ 2 Illuminator AN/PVS-7D w AN/PAQ-4C Laser Pointer	n=8 n=8 n=8
2	Night	AN/PVS-7D w VLI Tactical Flashlight AN/PVS-7D w AN/AN/PEQ 2 Illuminator AN/PVS-7D w AN/PAQ-4C Laser Pointer	n=8 n=8 n=8

3.3.1 Night Tests

There were three conditions for both nights of testing:

- biocular AN/PVS-7D NVG with VLI Tactical Flashlight (broad beam),
- biocular AN/PVS –7D NVG with AN/AN/PEQ-2A Illuminator (pinpoint), and
- biocular AN/PVS-7D NVG with AN/PAQ-4C Laser Pointer.

The purpose of night testing was to develop a rigorous set of data for target engagement performance with live ammunition at a variety of ranges for both static and moving targets. The use of these set target distances allowed investigators to determine system capabilities and limitations.

3.4 Trial Participants

Sixteen regular force infantrymen were recruited for this experiment from the 1st Battalion, Royal Canadian Regiment (1RCR) in Petawawa, Ontario. The mean age of the soldiers was 27.3 years (SD= 3.6, max = 30, min = 24). Half of the soldiers had 1 to 5 years of service, while the other half had 5 to 10 years of service in the reserves and regular force. The mean time since last Personal Weapons Test (PWT) for the soldiers was 6.8 months (SD=3.2, max = 12, min = 4). All soldiers had little to moderate training in urban operations and operational experience with NVG's. Twenty five percent of the soldiers wore glasses; none of them were colour blind.

3.5 Mounting of illuminators

The Laser Pointer and Illuminators were mounted on a special hand guard mounting system to soldiers' C7A1 rifles.

3.6 Weather Conditions

The weapon sights and NVG's were evaluated during seasonal weather conditions at Fort Benning, Georgia on 29 March and 10 April, 2002. The weather conditions observed by the experimenters are described in Table 2.

Table 2: Weather conditions

Date	Weather
29 March 2002 (Night)	Broken clouds
10 April 2002 (Night)	Broken clouds

3.7 Range Layout

The Malone 18 range in Fort Benning, Georgia was used for this trial. The range had seven static targets (at 50m, 100m, 150m, 175m, 200m, 250m and 300m) and five moving targets (at 35m, 60m, 75m, 125m, and 185m) from each of the nine set firing points (see Figure 5). Targets were set-up at 25m for soldiers to use when zeroing their weapons.

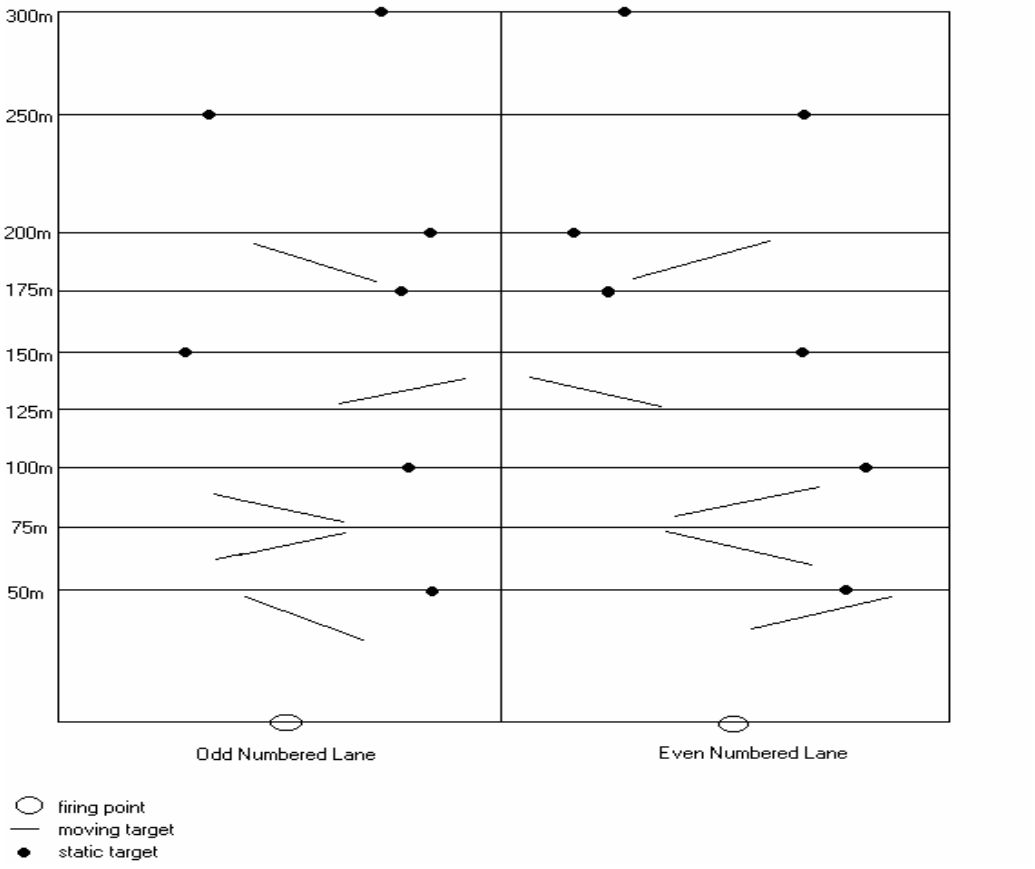


Figure 5: Target positions on Malone 18 range (not to scale)

Random scenarios were developed for target presentation. Each scenario included 15 static targets and 10 moving targets, for a total of 25 targets per serial (see Table 3).

Table 3: Targets comprising each serial

Description of Targets	Total
2 X 6 static targets	12
3 X 1 static target (at 100m)	3
2 X 5 moving targets	10
Total	**25**

3.8 Questionnaire Rating Scale

Soldiers rated the acceptability of the illumination systems on questionnaires using the following seven-point scale (see Figure 6).

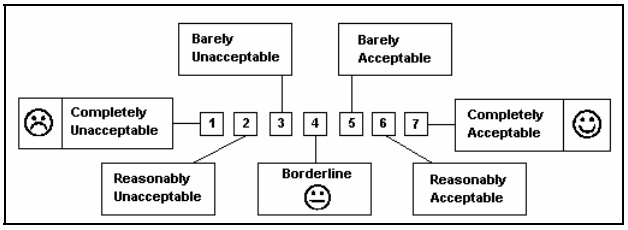


Figure 6: Standard rating scale

3.9 Data

Data collection focused on the following human factors (HF) criteria. Test content is described in more detail below. The order of test conditions was balanced as follows:

1. Visual acuity and Contrast Sensitivity;
2. Rifle Firing Performance – Accuracy;
3. Illuminance/Luminance Assessment; and
4. Exit Questionnaire.

3.9.1 Visual Acuity and Contrast Sensitivity

Prior to departing for the range, soldiers were screened for visual acuity and contrast sensitivity. A Snellen chart mounted on a well-lit office wall was used to test soldiers for visual acuity. Contrast sensitivity was assessed using the Contrast Sensitivity Test System.

During the night conditions with NVG's, the soldiers' visual acuity (smallest bar pattern) with each NVG system was measured using an ANV-20/20 night vision test device from Hoffman Engineering. Soldiers were screened to a minimum of 20/40 visual acuity with the NVG devices using a grid test pattern (see Figures 7a and 7b).

Figure 7a: ANV-20/20 NVD Infinity Focus System

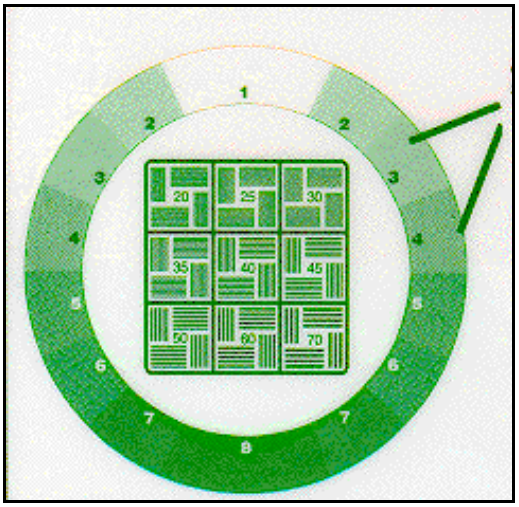


Figure 7b: ANV-20/20 acuity resolution pattern

3.9.2 Rifle Firing Performance - Accuracy

Rifle firing accuracy (hits) was recorded automatically for each target through the target controller interface. Targets were programmed such that one hit would drop the target.

3.9.3 Illuminance Assessment

Throughout each night of testing, ambient illuminance was measured with a photometer (see Section 3.7). All measurements were taken behind the firing points, facing the range (see Table 3).

3.9.4 Exit Questionnaire

Following the completion of target engagement serials, soldiers completed an Exit Questionnaire for all illuminator conditions (see Annex A). The soldiers were required to rate their overall acceptance of the illumination systems. The following 23 criteria were assessed:

- Vision /optical criteria
  - Light output
  - Beam width
  - Target illumination – close (0-100m)
  - Target illumination – far (100+m)
- Functionality criteria
  - Ease of mounting
  - Ease of zeroing
  - Maintenance of zero
  - Ease of battery charge
  - Ease of checking battery life
  - Light system bulk

- Light system weight
- Estimating durability

- Task demands criteria
  - Close-in target engagement
  - Far target engagement
  - Overall day engagement performance
  - Overall night engagement performance
  - Ease of maintenance
  - Ease of cleaning

- Compatibility criteria
  - Compatibility with the C7A1
  - Compatibility with the helmet
  - Compatibility with NVG systems

- Overall acceptance criteria
  - Overall acceptability of the lighting system for close quarters battle
  - Overall acceptability of the lighting system for open range battle.

3.10 Statistical Plan

A repeated measures analysis of variance for sights/vision system and day effects was conducted for all acceptability scale and performance results. Differences were identified at $p < .05$. All missing data points were replaced with the mean to prevent case-wise deletion of data. The statistical plan for the target engagement experiment was as follows:

Table 4: Statistical plan

Measure	Method	Analysis
Percentage of hits	Hits automatically recorded through Malone range target controller interface	ANOVA between: -Test conditions (3) -Target distance (12) -Moving/static targets (2)
Number of hits	Hits automatically recorded through Malone range target controller interface	ANOVA between: -Test conditions (3) -Moving/static targets (2)
Exit Questionnaire	Subjective assessment by participant	ANOVA between: -Test conditions (3) -Criteria (23)

4. Procedure

4.1 Set-up

Prior to the investigation, the training area at Fort Benning was examined and a suitable range location was requested. The Malone 18 range was used for this trial, as described in Section 3.8. The range had seven static targets (at 50m, 100m, 150m, 175m, 200m, 250m, and 300m) and five moving targets (at 35m, 60m, 75m, 125m, and 185m) from each of the nine set firing points (see Figures 5 above and 8 below). Targets were set up at 25m for soldiers to zero their weapon.

Figure 8: Malone 18 Range set-up

Nine random scenarios were developed for target presentation. Each scenario included 15 static targets and 10 moving targets, for a total of 25 targets per serial (see Table 4, section 3.8). Only four firing points were used for the live fire exercise.

4.2 Testing Procedures

At the beginning of the night, the scientific authority (DCIEM) measured ambient illumination at the range.

All the soldiers were briefed on the purpose of the experiment and test activities. A range and laser safety briefing was conducted prior to the start of the experimental tasks. Soldiers were briefed on the NVG and sighting systems, the procedures for attaching them to helmets, and adjusting and focusing the goggles. Soldiers had been previously screened for visual acuity and tested for contrast sensitivity by the scientific authority using a Snellen chart in a well-lit office. A briefing on shooting moving targets was given as the soldiers had limited experience on this range. Soldiers were given the evening to train on the range. They proceeded to dry bore sight the sighting systems using a laser bore light. Using targets set up at 25m, soldiers adjusted the

azimuth and elevation correction on their assigned sighting systems. During the training, each soldier shot 40 rounds (2 magazines) with a C7A1 with day sights. This gave them exposure to the target speed and location.

The first group of four soldiers was assigned their NVG and illuminators, and given the opportunity to dark-adapt outdoors. The soldiers were assisted with the procedures for attaching the NVG's to their helmet, and adjustment and focusing procedures. Visual acuity with each properly adjusted and focused NVG was taken with a Hoffman AN/AVS-20/20 NVD test system. As each group finished the preliminary NVG acuity testing, the soldiers were informed of the order on illumination conditions.

While the first group of soldiers was being briefed, the range was prepared. Power was hooked up to the targets and the range target controller tested the target presentation serials. Communication between target controllers and experimenters was tested.

When the testing began, the target controller ran the corresponding serial. As the soldiers detected a target, they aimed using instinctive aiming. Soldiers then engaged the target using two aimed single shots or an aimed double tap. This general test procedure was followed each night for all 16 soldiers on the range.

The soldiers picked up loaded magazines and an illumination system. After the first four soldiers completed all three conditions, the next four soldiers picked up loaded magazines and illumination systems and completed their three conditions. Upon completion of all conditions, the soldiers completed Exit Questionnaires and participated in a focus group.

5. Results

Throughout the Results section the following abbreviations are used for the different conditions tested (see Table 5). All significant findings are at the $p < .05$ level.

Table 5: Condition abbreviations

Condition	Abbreviation
biocular AN/PVS-7D with AN/PEQ-2A Illuminator	AN/PEQ-2A
biocular AN/PVS-7D with Visible Light Illuminator (Tactical Flashlight)	Tac Light
biocular AN/PVS-7D with AN/PAQ-4C Laser Pointer	AN/PAQ-4C
Unaided Vision with Visible Light Illuminator	VLI

5.1 Rifle Firing Performance

During the live fire trial, a target controller ran the corresponding serial. As the soldiers detected a target, they aimed using instinctive aiming. Soldiers then engaged the target using two aimed single shots or an aimed double tap. Rifle firing accuracy (hits) was recorded automatically for each target through the target controller interface. Targets were programmed such that one hit would drop the target.

5.1.1 Percentage of Hits - Static Targets

The percentages of hits on static targets for the three conditions are presented in Figure 9. The means and standard deviations for hits on static targets are presented in Table 6.

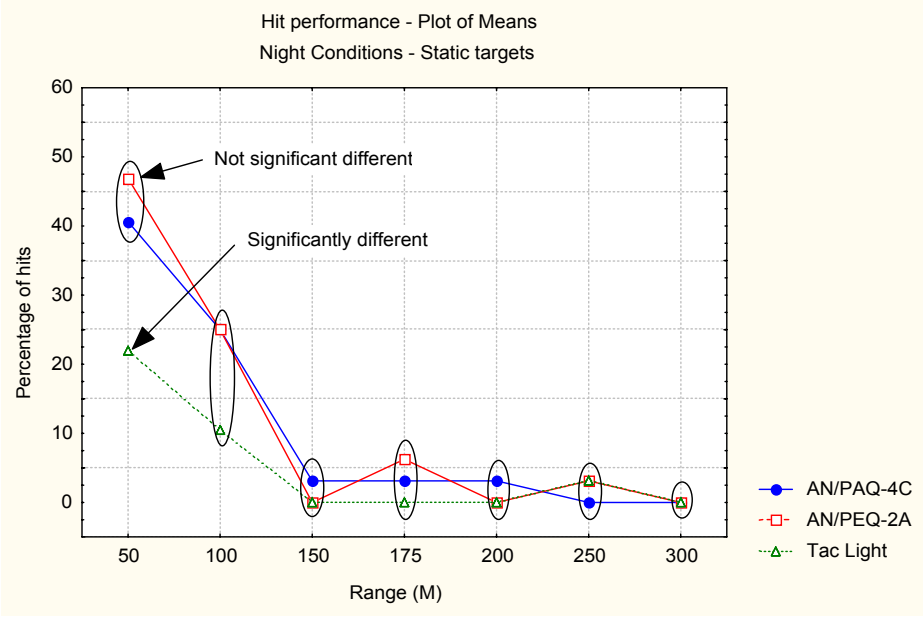


Figure 9: Percentage of hits on static targets

Table 6: Overall means and standard deviations on static targets

Range	Illumination	Mean (% hit)	SD (% hit)
50	AN/PEQ-4C	41	42
	AN/PEQ-2A	47	53
	Tactical Flashlight	22	31
100	AN/PEQ-4C	23	32
	AN/PEQ-2A	25	33
	Tactical Flashlight	10	16
150	AN/PEQ-4C	3	13
	AN/PEQ-2A	0	0
	Tactical Flashlight	0	0
175	AN/PEQ-4C	3	13
	AN/PEQ-2A	6	25
	Tactical Flashlight	0	0
200	AN/PEQ-4C	3	13
	AN/PEQ-2A	0	0
	Tactical Flashlight	0	0
250	AN/PAQ-4C	0	0
	AN/PEQ-2A	3	13
	Tactical Flashlight	3	13

The only significant difference found between the three illumination conditions across most of the static range conditions for target engagements was that the AN/PEQ-2A (47 % targets hit) and AN/PAQ-4C (41 % targets hit) systems had significantly more targets engaged than the Tactical Flashlight (22 % targets hit) at a 50m range. Furthermore, no differences were seen for long range (100m +) target engagement across all three systems.

In summary, the AN/PEQ-2A and AN/PAQ-4C out-performed the Tactical Flashlight for close target engagements only. The significant differences at each of the static target ranges are presented in Table 7.

Table 7: Significant differences on static targets for night conditions across all ranges

Significant Difference ($p<0.05$)
AN/PAQ-4C @ 50 m, AN/PEQ-2A @ 50 m > Tactical Flashlight @ 50 m

5.1.2 Percentage of Hits – Moving Targets

The percentages of hits on moving targets for the three conditions are presented in Figure 10. The means and standard deviations for hits on moving targets are presented in Table 8.

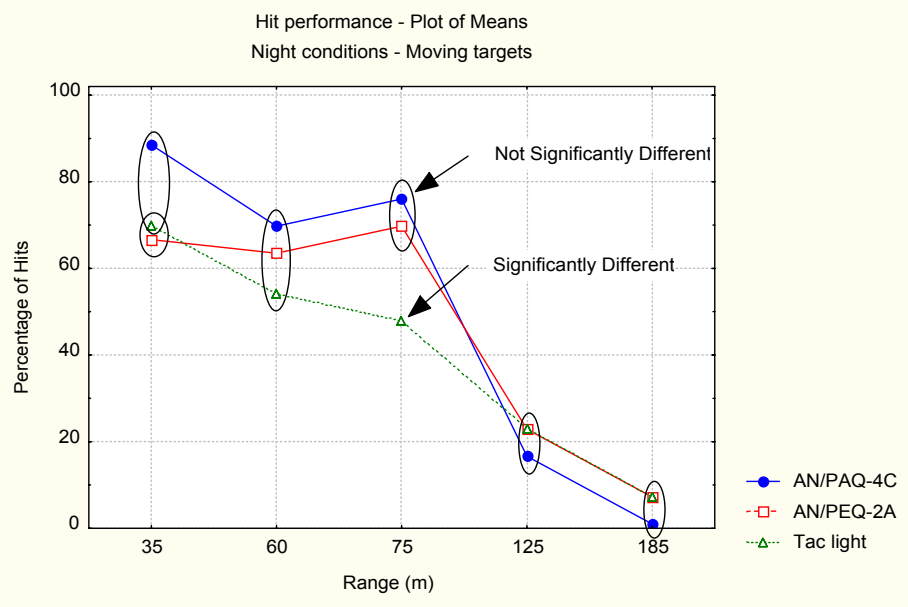


Figure 10: Percentage of hits on moving targets

Table 8: Overall means and standard deviations on moving targets

Range	Illumination	Mean (% hit)	SD (% hit)
35	**AN/PAQ-4C**	88	22
	AN/PEQ-2A	66	35
	Tactical Flashlight	69	40
60	**AN/PAQ-4C**	69	36
	AN/PEQ-2A	63	39
	Tactical Flashlight	53	43
75	**AN/PAQ-4C**	75	32
	AN/PEQ-2A	69	40
	Tactical Flashlight	47	43
125	**AN/PAQ-4C**	16	24
	AN/PEQ-2A	22	36
	Tactical Flashlight	22	36
185	**AN/PAQ-4C**	0	0
	AN/PEQ-2A	6	25
	Tactical Flashlight	6	36

There were few significant differences among the three conditions across the moving target ranges. However, at 35m, soldiers using the AN/PEQ-2A (66 % targets hit) hit significantly fewer targets than when they used the AN/PAQ-4C (88 % targets hit). Furthermore, at 75m,

soldiers hit significantly more targets when using either the AN/PEQ-2A (69 % targets hit) and the AN/PAQ-4C (75 % targets hit) than when they used the VLI Tactical Flashlight (47 % targets hit). No differences were seen for long range (100m +) target engagement across all three systems.

Thus, the AN/PEQ-2A and AN/PAQ-4C out-performed the VLI Tactical Flashlight for close range targets only. The significant differences at each of the moving target ranges are presented in Table 9.

Table 9: Significant differences on moving targets across ranges

Significant Difference (p<0.05)
AN/PAQ-4C @ 35m > AN/PEQ-2A @ 35 m
AN/PAQ-4C @ 75 m, AN/PEQ-2A @ 75 m > Tactical Flashlight @ 75 m

5.1.3 Percentage of Hits - Static versus Moving Targets

The percentages of hits on static versus moving targets for the three conditions are presented in Figure 11. The percentages are summarized in Table 10.

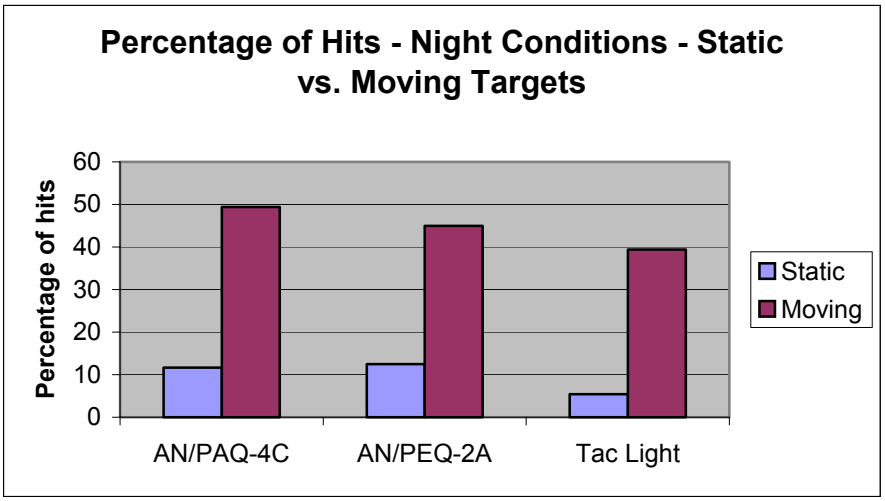


Figure 11: Percentage of hits on static versus moving targets

Table 10: Percentage of hits for static versus moving targets

Illuminators	Static		Moving	
	Mean (% hit)	S.D. (% hit)	Mean (% hit)	S.D. (% hit)
AN/PAQ-4C	11.7	11.0	49.4	16.5
AN/PEQ-2A	12.5	12.6	45.0	26.4
VLI Tactical Flashlight	5.4	5	39.4	26.4

There were no significant differences among the three conditions for moving target engagements. However, soldiers using either the AN/PEQ-2A (12.5 % targets hit) or the AN/PAQ-4C (11.7 % targets hit) hit significantly more targets than they did while using the VLI Tactical Flashlight (5.4% targets hit) for static targets.

To summarize, both the AN/PEQ-2A and the AN/PAQ-4C out-performed the VLI Tactical Flashlight against static targets. Significant differences between static targets and moving targets are presented in Table 11.

Table 11: Significant differences on moving targets across ranges

Target	Significant Difference (p<0.05)
Static	AN/PAQ-4C, AN/PEQ-2A > Tactical Flashlight
Moving	--

5.1.4 Number of hits – Static Targets

The number of hits on static targets for the three conditions is presented in Figure 12. The means and standard deviations are summarized in Table 12.

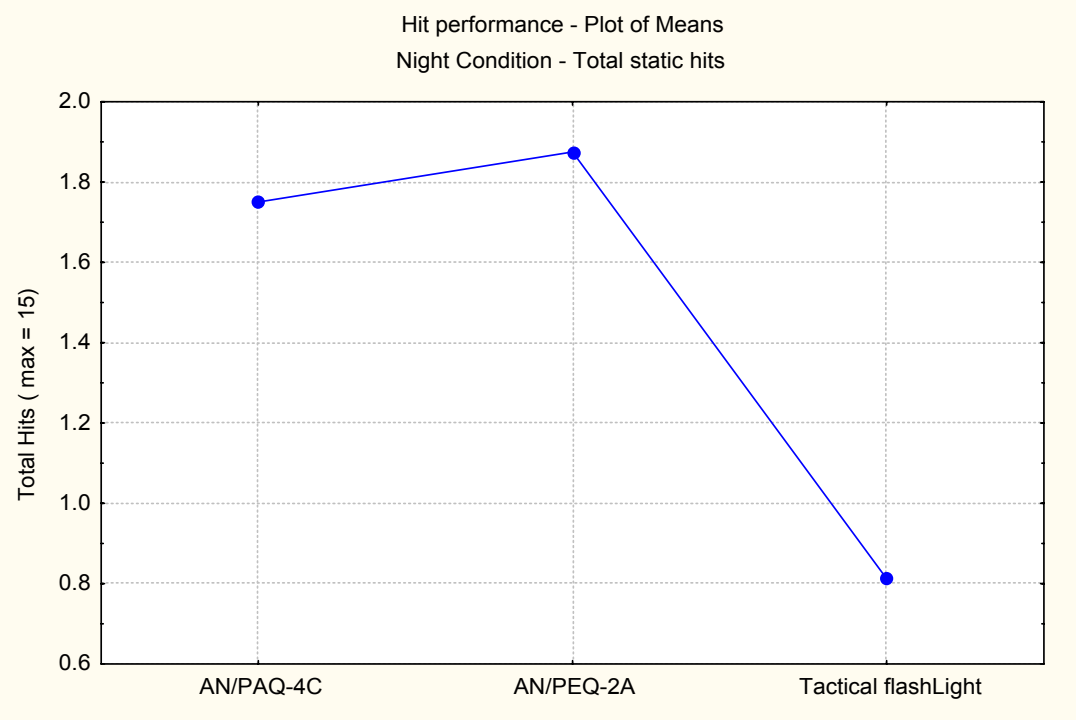


Figure 12: Number of hits on all static targets

Table 12: Means and standard deviations of hits on all static targets

Illuminators	Mean (# Rounds hit)	SD (# Rounds hit)
AN/PAQ-4C	1.8	1.7
AN/PEQ-2A	1.9	1.9
VLI Tactical Flashlight	0.8	0.8

Soldiers using either the AN/PAQ-4C (1.8 rounds hit) or the AN/PEQ-2A (1.9 rounds hit) hit significantly more rounds on the static target than VLI Tactical Flashlight (0.8 rounds hit).

Thus, soldiers using either the AN/PAQ-4C or the AN/PEQ-2A hit twice as many targets than when they used the VLI Tactical Flashlight. There were no other significant differences. A summary of the significant differences between the weapon sights across both target types and all ranges is presented in Table 13.

Table 13: Significant differences among illumination systems on all static targets

Significant Difference (p<0.05)
AN/PAQ-4C, AN/PEQ-2A > Tactical Flashlight

5.1.5 Number of Hits - Moving Targets

The number of hits on moving targets for the three conditions is presented in Figure 13. The means and standard deviations are summarized in Table 14.

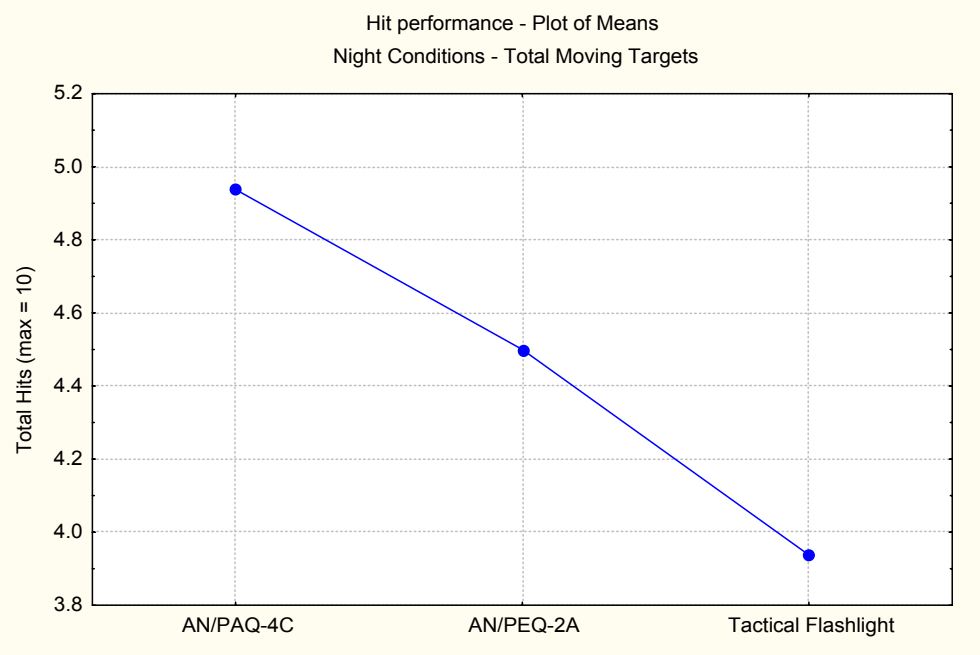


Figure 13: Number of hits on moving targets

Table 14: Means and standard deviations on all moving targets

Illuminators	Mean	SD
AN/PAQ-4C	4.9	1.7
AN/PEQ-2A	4.5	2.7
VLI Tactical Flashlight	3.9	2.6

No significant differences were seen among the three systems for the number of rounds hitting moving targets. The different illuminators did not affect detection of moving targets (Table 15).

Table 15: Significant differences on all moving targets

Significant Difference (p<0.05)
--

5.2 Exit Questionnaire

After the trial, each soldier completed a detailed Exit Questionnaire comparing their acceptance of each of the three illumination conditions with the biocular AN/PVS-7D NVG. Soldiers ranked each criterion using seven-point scales of acceptability (see figure 6). The Exit Questionnaire was split into the following sections: vision/optics, functionality, task demands, compatibility, and overall acceptance. The mean acceptability ratings for each criterion across all three illumination conditions are presented below.

5.2.1 Vision/Optics

The mean acceptability ratings for the vision/optics criteria from the detailed task questionnaire are presented in Figure 14. The vision /optics criteria included light output, beam width, target illumination – close (0-100m), and target illumination – far (100+m).

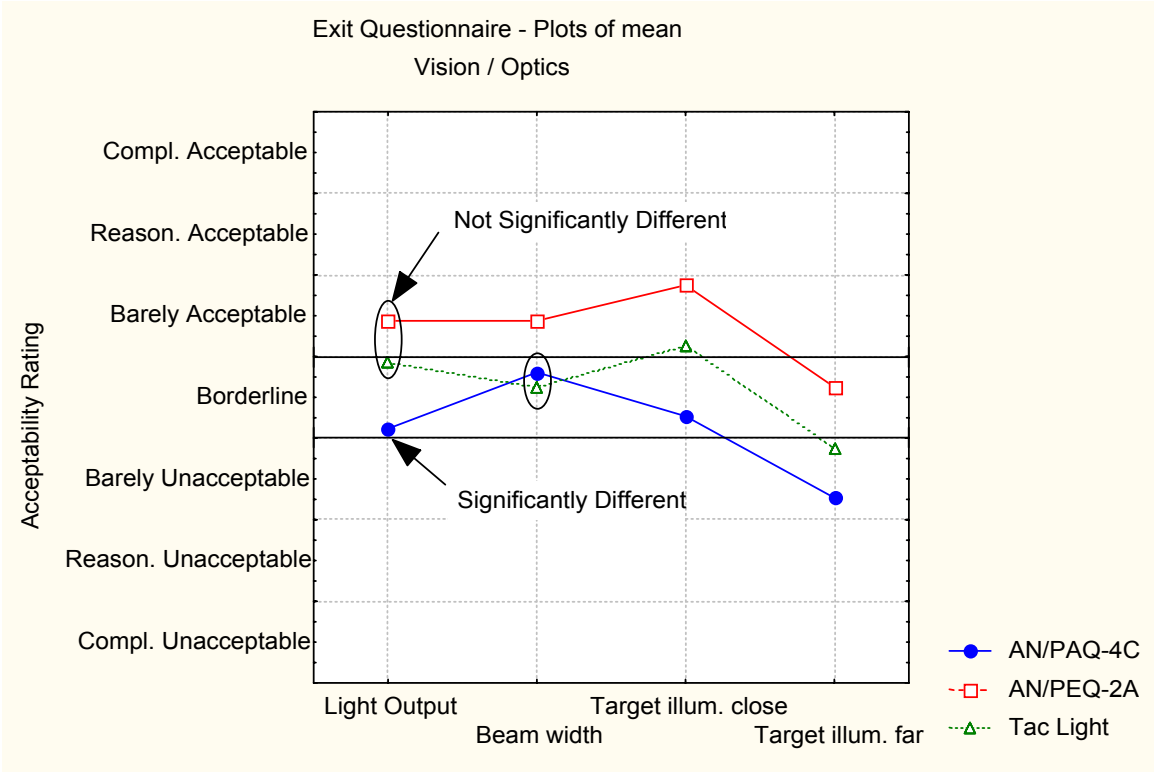


Figure 14: Acceptance ratings for vision/optics criteria

Overall, across all vision/optics criteria, the soldiers rated the AN/PEQ-2A "Barely Acceptable" and the VLI Tactical Flashlight and AN/PAQ-4C "Borderline". Across the three conditions, the AN/PEQ-2A was rated more acceptable than the AN/PAQ-4C and VLI Tactical Flashlight for vision/optics criteria. Overall, the VLI Tactical Flashlight illumination was significantly more acceptable than the AN/PAQ-4C illumination. No significant differences were seen between ratings for the AN/PEQ-2A and the VLI Tactical Flashlight for light output, or between the VLI Tactical Flashlight and AN/PEQ-4C for beam width.

In summary, the AN/PEQ-2A had a significantly better acceptability rating over both the VLI Tactical Flashlight and the AN/PAQ-4C for the vision/optics criteria. A summary of the significant differences between the sights for each vision/optics criterion is presented in Table 16.

Table 16: Significant differences between acceptance ratings for vision/optics criteria

Vision/Optics Criterion	Significant Differences (p<0.05)
Light output	AN/PEQ-2A, VLI Tactical Flashlight > AN/PAQ-4C
Beam width	AN/PEQ-2A > VLI Tactical Flashlight, AN/PAQ-4C
Target illumination – close (0-100m)	AN/PEQ-2A > VLI Tactical Flashlight > AN/PAQ-4C
Target illumination - Far (100+m)	AN/PEQ-2A > VLI Tactical Flashlight > AN/PAQ-4C

5.2.2 Functionality

The mean acceptability ratings for the functionality criteria are presented in Figure 15. The functionality criteria included ease of mounting, ease of zeroing, maintenance of zero, ease of battery change, ease of checking battery life, light system bulk, light system weight, and estimating durability.

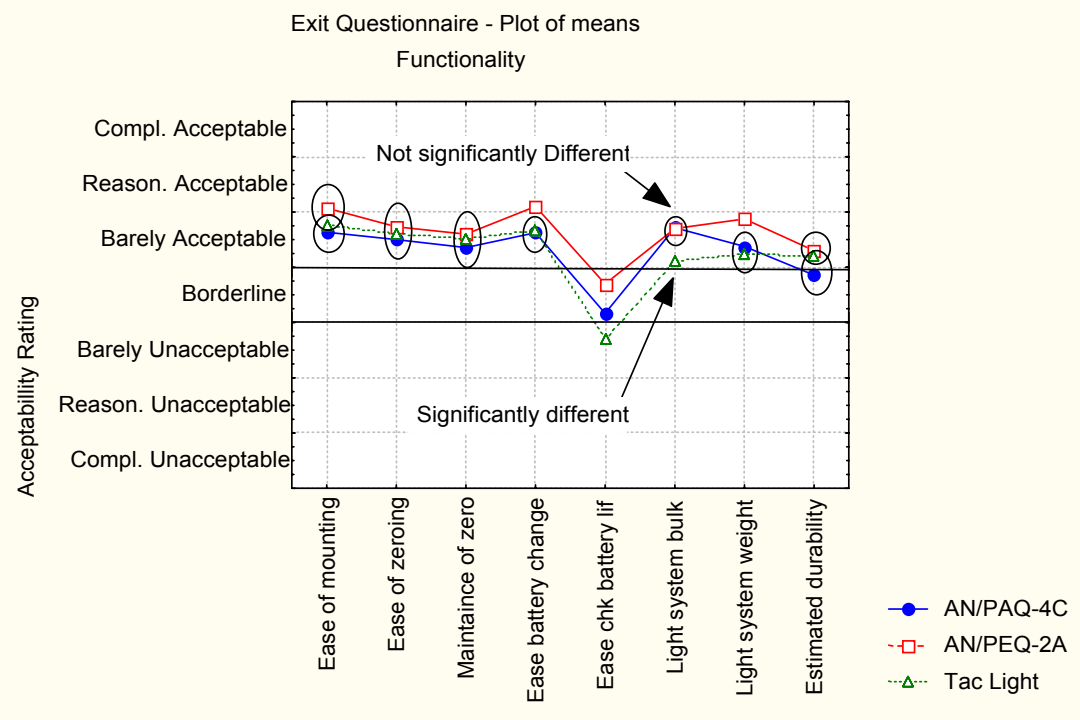


Figure 15: Acceptability Ratings for Functionality Criteria

In terms of functionality, the soldiers rated all three systems as ”Barely acceptable”. Across the three conditions, the AN/PEQ-2A was rated significantly more acceptable than the AN/PEQ-4C for ease of mounting, ease of battery changing, ease of checking battery life, light system weight, and estimated durability. Furthermore, the AN/PEQ-2A was more acceptable than the VLI Tactical Flashlight for ease of battery changing, ease of checking battery life, light system bulk, and light system weight. Overall, no significant differences were seen between the VLI Tactical Flashlight and the AN/PAQ-4C for most of the functionality criteria.

To summarize, the AN/PEQ-2A had a slightly better acceptance rating over VLI Tactical Flashlight for functionality criteria. A summary of the significant differences between the sights for each functionality criterion is presented in Table 17.

Table 17: Significant differences among acceptability ratings for functionality criteria

Functionality Criterion	Significant Differences (p<0.05)
Ease of mounting	AN/PEQ-2A > AN/PAQ-4C
Ease of zeroing	--
Maintenance of zero	--
Ease of battery changing	AN/PEQ-2A > AN/PAQ-4C, VLI Tac Light
Ease of checking battery life	AN/PEQ-2A > AN/PAQ-4C > VLI Tac Light
Light system bulk	AN/PEQ-2A, AN/PAQ-4C > VLI Tac Light
Light system weight	AN/PEQ-2A > VLI Tac Light, AN/PAQ-4C
Estimated durability	AN/PEQ-2A > AN/PAQ-4C

5.2.3 Task Demands

The mean acceptability ratings for task demands are presented in Figure 16. The task demands criteria included close-in target engagement, far target engagement, overall day engagement performance, overall night engagement performance, ease of maintenance, and ease of cleaning.

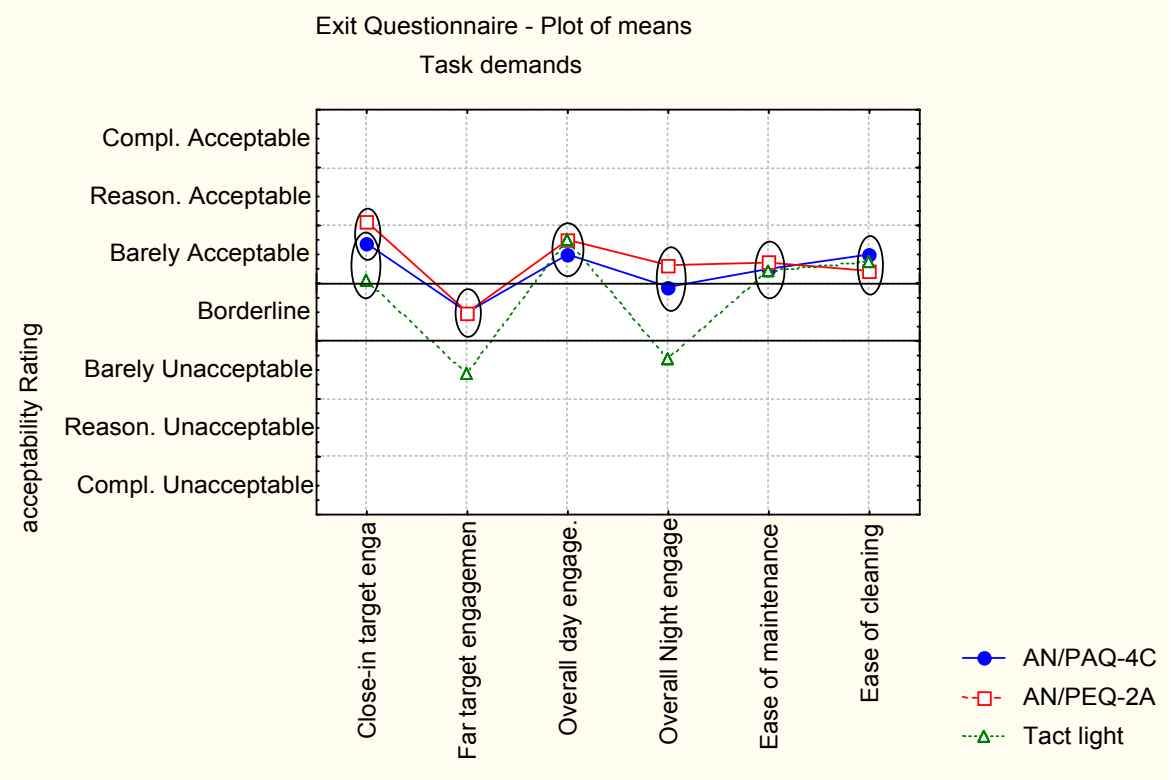


Figure 16: Acceptability ratings for task demand criteria

Overall, across task criteria, the participants rated the AN/PEQ-2A and the AN/PAQ-4C "Barely Acceptable" and the VLI Tactical Flashlight as "Borderline. No significant differences were seen among the three conditions for overall target engagement, ease of maintenance, and ease of

cleaning. Furthermore, no significant differences were seen between the AN/PEQ-2A and the AN/PAQ-4C across all task criteria. The AN/PEQ-2A and the AN/PAQ-4C were rated significantly more acceptable than the VLI Tactical Flashlight for far target engagement and overall night engagement. Furthermore, the AN/PEQ-2A was significantly more acceptable than the VLI Tactical Flashlight for close-in target engagement.

Thus, the AN/PEQ-2A had a significantly better acceptance rating over the VLI Tactical Flashlight for task criteria. No differences were seen between the AN/PEQ-2A and the AN/PEQ-4C for acceptability ratings on task criteria. A summary of the significant differences between the sights for each task demand criterion is presented in Table 18.

Table 18: Significant differences in acceptability ratings for task demand criteria

Task Demands Criterion	Significant Differences (p<0.05)
Close-in target engagement	AN/PEQ-2A > VLI Tac Light
Far target engagement	AN/PEQ-2A, AN/PAQ-4C >VLI Tac Light
Overall day engagement performance	--
Overall night engagement performance	AN/PEQ-2A, AN/PAQ-4C > VLI Tac Light
Ease of maintenance	--
Ease of cleaning	--

5.2.4 Compatibility

The mean task acceptability ratings for the compatibility criteria are presented in Figure 17. The compatibility criteria consisted of compatibility with the C7A1, the helmet, the equipment, and the NVG system.

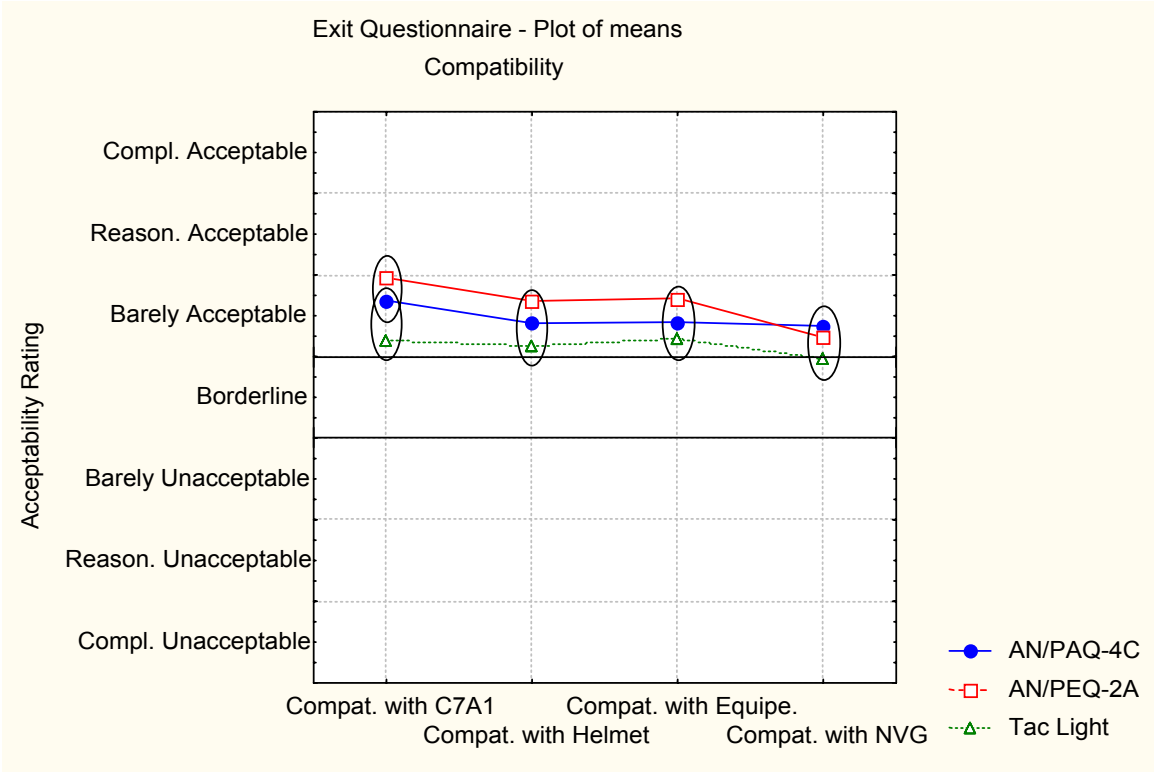


Figure 17: Acceptability ratings for compatibility criteria

Overall, across compatibility criteria, the soldiers rated the AN/PEQ-2A, the AN/PAQ-4C and the VLI Tactical Flashlight "Barely Acceptable". No significant differences were seen among the three conditions for compatibility with the helmet, the equipment, and the NVG system. The AN/PEQ-2A was significantly more acceptable than the AN/PEQ-4C for compatibility with the C7A1.

In summary, no significant differences were found among the three systems for acceptability ratings on compatibility criteria overall. A summary of the significant differences between the sights for each compatibility criterion is presented in Table 19.

Table 19: Significant difference in acceptability ratings for compatibility criteria

Compatibility Criterion	Significant Differences (p<0.05)
Compatibility with C7A1	AN/PEQ-2A > Tactical Flashlight
Compatibility with helmet	--
Compatibility with equipment	--
Compatibility with NVG systems	--

5.2.5 Overall Acceptance

The mean overall acceptance ratings are presented in Figure 18. The overall acceptance criteria included overall acceptability of the lighting system for close quarters battle and overall acceptability of the lighting system for open range battle.

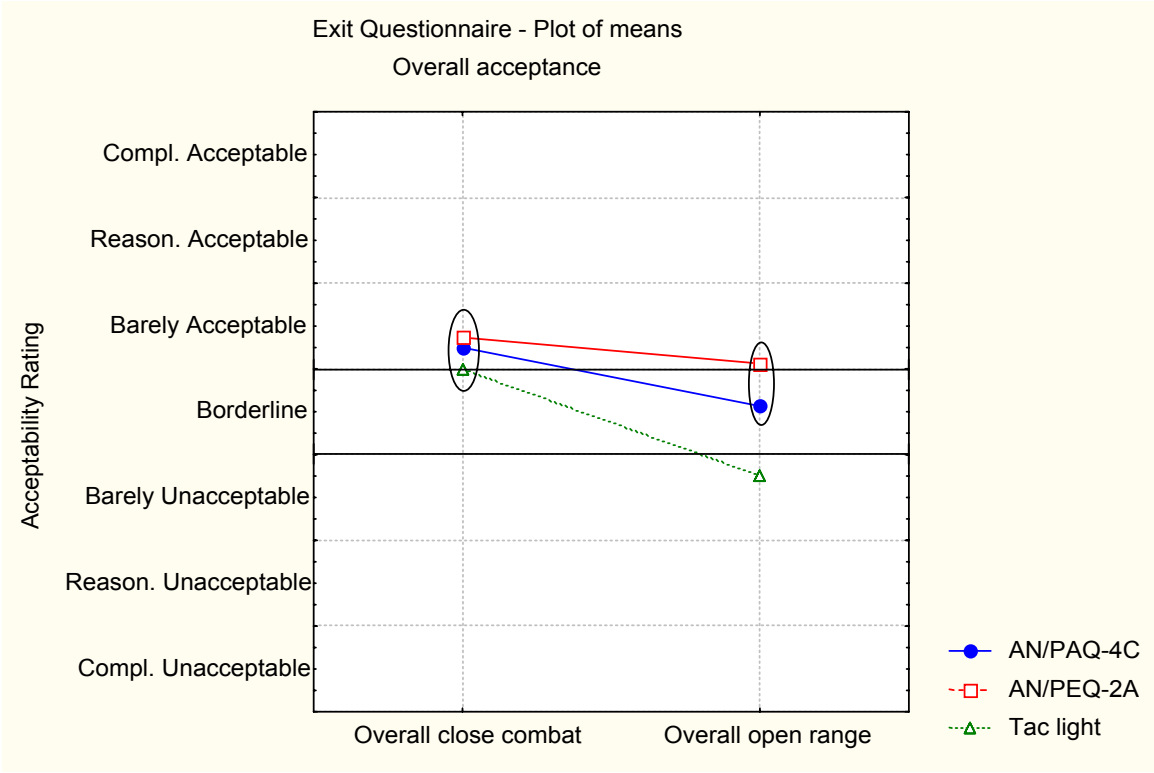


Figure 18: Acceptability ratings for overall Acceptance criteria

Overall, across compatibility criteria, the soldiers rated the AN/PEQ-2A and the AN/PAQ-4C "Barely Acceptable", and the VLI Tactical Flashlight "Borderline". No significant differences were seen among the three conditions for overall acceptability of the lighting system for close quarters battle. However, the AN/PEQ-2A and the AN/PAQ-4C were significantly more acceptable than the VLI Tactical Flashlight for overall acceptability of the lighting system for open range battle.

In conclusion, no significant differences were found among the three systems for overall close combat criteria. A summary of the significant differences between the sights for each overall acceptance criterion is presented in Table 20.

Table 20: Significant Differences in Acceptance Ratings for Overall Acceptance Criteria

Overall Acceptance Criterion	Significant Differences (p<0.05)
Overall acceptability of the lighting system for close quarters battle	--
Overall acceptability of the lighting system for open range battles	AN/PEQ-2A, AN/PAQ-4C > Tactical Flashlight

5.3 Focus Group Discussion

The exit focus group occurred after all soldiers had exposure to the different illuminators. A summary of the comments made by the participants about the illuminators and biocular AN/PVS-7D NVG during the focus group discussion is presented below.

The soldiers were pleased with the AN/PEQ-2A's lightweight and compact design. They especially liked the longer illumination range. However, the AN/PEQ-2A gave away the soldier's position and had the habit of masking the lit up target, and, thus, they preferred the system for indoor use.

The soldiers liked the AN/PAQ-4C's ease of aiming and use, especially against close target engagements. However, the laser aimer dot either masked targets at long range or the dot could not be seen at long range. Thus, the soldiers preferred the AN/PAQ-4C for close range engagements.

The soldiers liked the VLI Tactical Flashlight in an urban environment as it lit up the close targets and allowed for quick target engagement. However, the tactical illuminator was too heavy/too big/too bulky, and had poor range due to poor brightness, poor illumination range, and poor beam width.

In summary, the soldiers preferred the AN/PEQ-2A illuminator to both the VLI Tactical Flashlight and the AN/PAQ-4C for short-range engagement. Furthermore, all three systems received positive feedback on possible use in built-up areas, but overwhelmingly negative feedback for long-range target detection.

6. Discussion

The AN/PAQ-4C Laser Pointer and AN/PEQ-2A IR Illuminator scored significantly more hits for short range target engagements than the VLI Tactical Flashlight. This indicates that both the AN/PAQ-4C Laser Pointer and AN/PEQ-2A Illuminator performed better at short range (less than 100m) target shooting.

With regard to long-range target engagement performance or for moving targets, there were no significant differences among the AN/PAQ-4C Laser Pointer, VLI Tactical Flashlight and the AN/PEQ-2A Illuminator; the illumination did not improve the soldiers' performance in these areas. However, soldiers using the AN/PAQ-4C Laser Pointer and AN/PEQ-2A Illuminator scored significantly more hits against static targets than the VLI Tactical Flashlight, indicating that these illuminators improved the soldiers' detection of static targets on the range.

With regard to acceptability, the AN/PEQ-2A Illuminator had a significantly better acceptability rating over the VLI Tactical Light and the AN/PAQ-4C Laser Pointer for vision/optical criteria. Furthermore, the AN/PEQ-2A illuminator had a significantly better acceptability rating over the VLI Tactical Flashlight for functionality and task criteria. In addition, the AN/PEQ-2A and AN/PAQ-4C had significantly better acceptability ratings over the VLI Tactical Flashlight for overall open range criteria. Overall, no significant differences were found among the three systems for acceptability ratings on compatibility and overall close combat criteria. Thus, these findings indicate that the AN/PEQ-2A was more acceptable to the soldiers than the VLI Tactical Flashlight for this trial.

6.1 Limitations

The illumination systems were to be compared using the same NVG units. However, the participants did not like the biocular AN/PVS-7D NVG system used in this trial. Considering the fact that both poor resolution and over-powering illumination can mask the target from detection, these may have influenced target detection performance. Therefore, a direct comparison of different types of illumination systems was impacted by the use of the current NVG system and may have changed once the resolution characteristic was altered on the NVG system.

Moreover, the current NVG system has a restricted field of view (FOV) of 40°. Therefore, the benefit of increased area of illumination on target detection could not be thoroughly evaluated. The small field of view limited the area seen by the soldier and consequently the illumination effects of the AN/PAQ-4C were likely influenced less by limited FOV.

7. Recommendations

Based on these results, use of the AN/PAQ-4C Laser Pointer and AN/PEQ-2A Illuminator at night may be advantageous to light infantrymen for close range (less 100m) targets and static targets. In the present study, soldiers hit more static and close range targets using the AN/PAQ-4C Laser Pointer and AN/PEQ-2A Illuminator than when using the VLI Tactical Flashlight. Future studies should continue to examine the performance of soldiers using the biocular AN/PVS-7D as well as other types of NVG's with both the AN/PAQ-4C Laser Pointer and AN/PEQ-2A Illuminator to further compare their advantages and disadvantages.

In addition, most soldiers commented on the acceptability of the VLI Tactical Flashlight, the AN/PEQ-2A Illuminator, and the AN/PAQ-4C Laser Pointer for fighting in built-up areas. Thus, another area of future study should be to investigate different illuminators in urban target detection and house clearing conditions.

Finally, future study in illumination systems should investigate the affects of different illuminator intensity and beam area coverage on open range targets and urban target detection, as this study suggests that limited resolution and FOV influence the benefit that the soldier receives from the illumination system. In order to remove the impact of NVG resolution and FOV, regular flashlights could be used to test the impact that illumination intensity and area coverage have on target detection.

8. References

A. CUQLOCK-KNOPP, V.G., TORGERSON, W., SIPES, D.E., BENDER, E. and MERRITT, J.O. (1995) A Comparison of Monocular, Biocular, and Binocular Night Vision Goggles for Traversing Off-road Terrain on Foot. (ARL-TR-747). Aberdeen Proving Ground, MD; U.S. Army Research Laboratory

B. BOFF, K.R. and LINCOLN, J.E (Eds.) (1988). Engineering Data Compendium: Human Perception and Performance, Volumes I and II. Wright-Patterson Air Force Base, OH

C. VELGER, M. (1998). Helmet-mounted displays and sights. Norwood MA: Artech House Inc.

D. MCLEAN, W.E., RASH, C.E., MCENTIRE, J.E., BRAITHWAITE, M.G. and MORA, J.C., (1997). A Performance History of AN/PVS-5 and ANVIS Image Intensification Systems in U.S. Army Aviation. Proceedings of SPIE – The International Society for Optical Engineering, 3058

E. CALDWELL, J.L., CORNUM, R.L.S., STEPHENS, R.L. and RASH, C.E. (1990). Visual processing: Implications for helmet mounted displays, Proceedings of SPIE – The International Society for Optical Engineering, 1290

F. LEGER, A., ROUMES, C., GARDELLES, C., CURSOLLE, J.P. and KRAUS, J.M. (1988). Binocular HMD For Fixed-Wing Aircraft: A Trade-Off Approach. Proceedings of SPIE – The International Society for Optical Engineering, 1988

G. ANGEL, H.A. (2004). Examination of the Effect of Night Vision Devices on Dismounted Terrain Traverse. CR2004-176. Toronto:ON, *Defence Research and Development Canada – Toronto*.

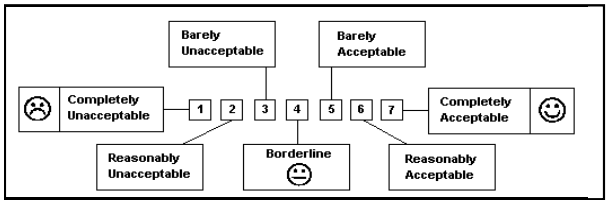
H. ANGEL, H.A. (2004). A Comparison of Monocular, Biocular and Binocular Night Vision Goggles with and without Laser Aiming Devices for Engaging Targets in a Bush-lane. CR2004-172. Toronto:ON, *Defence Research and Development Canada – Toronto*.

I. ANGEL, H.A., COLBERT, H.J., (2004). Examination of the Effect of Night Vision Devices on C7A1 Target Engagement Accuracy. CR2004-173. Toronto:ON, *Defence Research and Development Canada – Toronto*.

J. ANGEL, H.A. and GAUGHAN, P.M., (2005). Examination of the Effect of Night Vision Devices on Rifle Target Engagement Accuracy During Urban Operations. CR2005-066. Toronto:ON, *Defence Research and Development Canada – Toronto*.

K. ANGEL, H.A., MASSEL, L.J., (2005). Examination of the Effect of Night Vision Devices on Rifle Target Engagement Accuracy During Bush Lane Engagements. CR2005-069. Toronto:ON, *Defence Research and Development Canada – Toronto*.

Annex A:
Exit Questionnaire



PERSONNEL INFORMATION	**Clearly print your subject number, and indicate the illumination system. Please note some o f the questions may not apply to all systems.**

Subject Number: ☐☐☐	**Illumination: None ○ PEQ 2A ○ Tactical Light ○**	
Please rate the following criteria	**Acceptance Rating** ☹ **1 2 3** 😐 **4 5 6** ☺ **7**	**Comments**
VISION/OPTICS		
Light output	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Beam width	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Target illumination - close (0-100m)	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Target illumination - far (100m+)	☐ ☐ ☐ ☐ ☐ ☐ ☐	
FUNCTIONALITY		
Ease of mounting	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of zeroing	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Maintenance of zero	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of battery changing	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of checking battery life	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Light system bulk	☐ ☐ ☐ ☐ ☐ ☐ ☐	

Please rate the following criteria	Acceptance Rating ☹ 1 2 3 😐 4 5 6 ☺ 7	Comments
FUNCTIONALITY		
Light system weight	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Estimated durability	☐ ☐ ☐ ☐ ☐ ☐ ☐	
TASK DEMANDS		
Close-in target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Far target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Overall day engagement performance	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Overall night engagement performance	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Compatibility with C7A1	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Compatibility with helmet	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Compatibility with equipment	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Compatibility with NVG systems	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of maintenance	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of cleaning	☐ ☐ ☐ ☐ ☐ ☐ ☐	

OVERALL ACCEPTANCE		
Overall acceptability of the lighting system for close quarters battle	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Overall acceptability of the lighting system for open range battle	☐ ☐ ☐ ☐ ☐ ☐ ☐	
COMMENTS		

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(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

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Harry A. Angel; Philip M. Gaughan; Paul G.S. Vilhena

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(U) The main aim of this field trial was to assess the capabilities of illumination systems (biocular AN/PVS−7D night vision goggles, the Visible Light Illuminator (VLI) Tactical Flashlight, the AN/PEQ−2A Illuminator, and the AN/PAQ−4C Laser Pointer) during static and moving (dynamic) target engagement using live ammunition (on the Malone 18 range).

Soldiers using the AN/PAQ−4C Laser Pointer and AN/PEQ−2A illuminator scored significantly more hits for short−range target engagements than with the VLI Tactical Flashlight. Conversely, there were no significant differences among the three illuminators for long−range target engagements. This indicates that any of the three types of illumination improved soldiers' long−range (100+ m) target shooting performance on the Malone 18 range.

Overall, soldiers using the AN/PAQ−4C Laser Pointer and AN/PEQ 2A Illuminator scored significantly more hits against static targets than when using the VLI Tactical Flashlight. However, there were no significant differences observed among the three illumination conditions against moving targets, suggesting that none of the systems tested in this study improved the soldiers' detection or engagement of moving targets on the range more than the others.

The AN/PEQ−2A Illuminator had a significantly better acceptability rating over the VLI Tactical Flashlight for functionality, task, vision/optics, and overall open range criteria as well as a significantly better acceptability rating over the AN/PAQ−4C Laser Pointer for vision/optics criteria. This indicates that the AN/PEQ−2A illuminator was more acceptable overall to the soldiers than both either the VLI Tactical Flashlight and the AN/PAQ−4C Laser Pointer.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Soldier Information Requirements Technology Demonstration Project; SIREQ TD; night vision goggles; NVG; Visible Light Illuminator; VLI; Tactical Flashlight; Illumination; AN/PEQ−2A; AN/PAQ−4C; Laser Pointer; target engagement