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EXAMINATION OF THE EFFECT OF OFF-BORE SHOOTING ON RIFLE TARGET ENGAGEMENT ACCURACY DURING SIMULATED ENGAGEMENTS

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Abstract

A 6-day laboratory study was undertaken at Defence Research and Development Canada (DRDC) Toronto, Canada over the period September 21 to September 28, 2001. Twelve-reserve force infantry soldiers assessed the engagement performance of two different off-bore sights, the unmagnified U.S. Land Warrior system and the magnified DCIEM[1] Helmet Mounted Gunsight, against two conventional sights (magnified optical C79 and unmagnified Iron), in a small arms simulator. The shooting tests consisted of a test of time to aim, and tests of shooting precision in the prone and standing position against static and moving targets.

The results of time to aim indicated difficulty in quickly aiming with the unmagnified off-bore sight (Land Warrior), and minimal difference in aiming time between the magnified off-bore sight and the conventional sights. Shooting precision was found to be equal between off-bore and on-bore sights, with one exception. Shooting precision was better with the C7 optical sight in comparison to the Land Warrior when participants were in the prone posture. In the gallery range, the magnified off-bore sight performed as well as the magnified optical C79 sight; whereas, the unmagnified off-bore sight performed the worst. For moving targets, the magnified off-bore sight was not tested, and the conventional sights generally outperformed the unmagnified off-bore sight, but only marginally at close (<50m) distances.

Based on observations and results from this study, recommendations for future research and investigations are discussed

[1] Defence and Civil Institute of Environmental Medicine

Résumé

Une étude en laboratoire de 6 jours a été effectuée en Géorgie par Recherche et développement pour la défense Canada (RDDC) – Toronto, du 21 au 28 septembre 2001. Douze fantassins de la Force de réserve ont évalué le rendement d'engagement de deux viseurs hors axe différents, le système U.S. Land Warrior sans grossissement et le viseur monté sur casque à grossissement de l'IMED[2], par comparaison avec deux viseurs classiques (le viseur optique C79 à grossissement et le viseur Iron sans grossissement), dans un simulateur d'armes légères. Les essais de tir comprenaient un essai de temps de pointage et des essais de précision du tir, en positions couchée et debout, sur des objectifs fixes et mobiles.

Les résultats du temps de pointage ont fait ressortir la difficulté d'un pointage rapide avec le viseur hors axe sans grossissement (Land Warrior) et la différence minimale du temps de pointage entre le viseur hors axe à grossissement et les viseurs classiques. La précision de pointage s'est avérée égale pour ce qui est des viseurs hors axe et dans l'axe, à une exception près. Lorsque les participants étaient en position couchée, la précision de pointage du viseur optique C79 était meilleure que celle du viseur Land Warrior. Sur le champ de tir à tranchée, le viseur hors axe à grossissement a donné un rendement égal au viseur optique C79 à grossissement, alors que le viseur hors axe sans grossissement s'est révélé le pire. Dans le cas des objectifs mobiles, le viseur hors axe à grossissement n'a pas été soumis aux essais et les viseurs classiques ont généralement dépassé le viseur hors axe sans grossissement, mais seulement de peu et à courte distance (< 50 m).

Selon les observations et les résultats de cette étude, des recommandations de recherches et études futures sont examinées.

[2] Institut de médecine environnementale pour la défense

Executive Summary

Helmet Mounted Displays (HMD's), in conjunction with weapon mounted video sights, have been suggested as a method for increasing a soldier's survivability in combat. Referred to as "off-bore" shooting, this technology lets the soldier aim and shoot from behind cover, thereby exposing only the hands and forearms to enemy fire.

The accuracy of two different off-bore sights, the unmagnified U.S. Land Warrior system and the magnified DCIEM[3] Helmet Mounted Gunsight, compared to two conventional sights (magnified optical C79 and unmagnified Iron), were measured by shooting tests performed in a small arms simulator. The shooting tests consisted of a test of time to aim, and three tests of accuracy in standing and prone shooting postures. The three accuracy tests consisted of a shooting precision measure, gallery range scenario, and a moving target scenario.

The results of time to aim indicated difficulty in quickly aiming with the unmagnified off-bore sight (Land Warrior), and minimal difference in aiming time between the magnified off-bore sight and the conventional sights. Shooting precision was found to be equal between off-bore and on-bore sights, with one exception. Shooting precision was better with the C7 optical sight in comparison to the Land Warrior when participants were in the prone posture. In the gallery range, the magnified off-bore sight performed as well as the magnified optical C79 sight; whereas, the unmagnified off-bore sight performed the worst. For moving targets, the magnified off-bore sight was not tested, and the conventional sights generally outperformed the unmagnified off-bore sight, but only marginally at close (<50m) distances.

In conclusion, this work suggests that magnification may be more important than whether a sight is on or off-bore. Shooting accuracy can be as good for an off-bore sight in comparison to a conventional sight. To reduce aiming time in future off-bore sights, higher resolution, fast refresh rate video sights with effective automatic light exposure may need to be developed. More studies using the DCIEM Helmet Mounted Gunsight, which compared favourably to the optical C79 sight, need to be conducted, as well as off-bore testing in a live-fire range.

[3] Defence and Civil Institute of Environmental Medicine

Sommaire

Les afficheurs montés sur casque (HMD), associés aux viseurs vidéo montés sur arme, ont été proposés comme moyens d'améliorer la surviabilité d'un soldat au combat. Cette technologie, connue sous l'appellation de tir « hors axe », permet au soldat de pointer son arme et de tirer à couvert, n'exposant ainsi que ses mains et ses avant-bras au tir ennemi.

Des essais de tir effectués dans un simulateur d'armes légères ont permis de mesurer la précision de deux viseurs hors axe différents, le système U.S. Land Warrior sans grossissement et le viseur monté sur casque à grossissement de l'IMED[4], par comparaison avec deux viseurs classiques (le viseur optique C79 à grossissement et le viseur Iron sans grossissement). Les essais de tir comprenaient un essai de temps de pointage et trois essais de précision, en positions de tir debout et couchée. Les trois essais de précision incluaient une mesure de précision du tir, un scénario sur champ de tir à tranchée et un scénario de tir sur objectif mobile.

Les résultats du temps de pointage ont fait ressortir la difficulté d'un pointage rapide avec le viseur hors axe sans grossissement (Land Warrior) et la différence minimale du temps de pointage entre le viseur hors axe à grossissement et les viseurs classiques. La précision de pointage s'est avérée égale pour ce qui est des viseurs hors axe et dans l'axe, à une exception près. Lorsque les participants étaient en position couchée, la précision de pointage du viseur optique C79 était meilleure que celle du viseur Land Warrior. Sur le champ de tir à tranchée, le viseur hors axe à grossissement a donné un rendement égal au viseur optique C79 à grossissement, alors que le viseur hors axe sans grossissement s'est révélé le pire. Dans le cas des objectifs mobiles, le viseur hors axe à grossissement n'a pas été soumis aux essais et les viseurs classiques ont généralement dépassé le viseur hors axe sans grossissement, mais seulement de peu et à courte distance (< 50 m).

En conclusion, cette étude révèle que le grossissement peut être plus important que le positionnement du viseur dans l'axe ou hors axe. La précision de tir peut être aussi bonne pour un viseur hors axe que pour un viseur classique. Afin de réduire le temps de pointage des futurs viseurs hors axe, il pourrait s'avérer nécessaire de développer des viseurs vidéo à résolution supérieure, à haute vitesse de régénération et à commande automatique efficace de l'exposition lumineuse. D'autres études s'imposent relativement au viseur monté sur casque de l'IREM, qui s'est comparé favorablement au viseur optique C79, et des essais hors axe devront être effectués sur un champ de tir réel.

[4] Institut de médecine environnementale pour la défense

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1 Background

A critical soldier task is to detect, recognize, identify, and engage targets. This task, however, must be balanced against the need for survivability. Target acquisition (detection, recognition and identification) generally increases with exposure duration and target size; and while one soldier is trying to detect the enemy, the reverse is true as well. Without the benefit of other cues, well-camouflaged targets make detection difficult. One means of improving acquisition is to increase search duration and one means of reducing self-detection is to reduce target size. During World War I, soldiers in all armies used trench periscopes to monitor "No Man's Land" without exposing themselves to enemy fire (see Figure 1).

Figure 1: World War I trench periscope

Some periscopes were used with off-bore weapon systems. Soldiers would use these to aim remotely triggered tripod mounted weapons.

Operations in an urban environment are particularly hazardous for attacking soldiers. Enemy soldiers are usually well camouflaged and, therefore, the attackers are forced to expose themselves around corners, in windows, etc. As a consequence, the Canadian Land Forces is currently revising its urban operations doctrine. The previous doctrine was based on hard-learned lessons of the Italian Campaign during World War II. This doctrine favoured the overwhelming use of smoke, fragmentation grenades, and automatic fire to clear rooms and buildings. While this approach may work well in a full-scale war, it is not appropriate in the spectrum of war and conflicts the Canadian Land Forces face today. Revised doctrine identifies the reduced use of area weapons and automatic fire in urban operations, shifting towards aimed shots. As an indication of the manifestation of doctrine in training, Canadian soldiers are currently taught to use the mirrors on their Silva compasses to scan around corners, over walls, in doorways, etc.

There are a number of new sighting systems, which do support urban operations. These include reflex sights and laser sights. While the benefits of these aiming sights are well known, soldiers still have to expose themselves when acquiring targets. Over the past 10 years, therefore, DCIEM has investigated the use of weapon-mounted sensors and helmet mounted sights to overcome this risk. With only the arms exposed to enemy fire, such indirect or "off-bore" shooting offers significant improvements to survivability and lethality for the soldier (see Figure 2). However, studies investigating the accuracy of off-bore head mounted sight (HMS) systems compared to conventional on-bore sights have been minimal.

Figure 2: Off-bore shooting using the US Land Warrior System

While visual perception research and field studies have identified a number of advantages and disadvantages with monocular, and binocular HMS's in an aviation environment (Wells & Griffin (1987), Velger (1998) and Caldwell, Cornum, Stephens, & Rash, 1990), the majority of these have used head-tracking for air-to-air aiming. HMS's are known to aid in relieving the high workload of a pilot of a fighter aircraft.

However, very few controlled studies on dismounted soldier off-bore target engagement performance have been identified. Due to the sensitive nature of the subject, reported studies on target engagement performance with the current version of the United States Army's Land Warrior HMS are unavailable. As a result, it is not well understood how well they impact the shooting performance of dismounted infantry.

Off-bore shooting requires a soldier to hold the rifle in unusual ways, such as holding it at the hip or off of the shoulder. Given that the degree of control over a rifle has been shown to be a

significant factor in firing performance (References G and H), it is unclear whether shooting performance will be impacted negatively or positively when soldiers engage in off-bore shooting.

In order to address this query, the SIREQ-TD Project has sponsored a series of scientific investigations to characterize soldier performance with off-bore HMS systems. These studies include the laboratory trial described herein, as well as two future field trials. The goal of these is to compare conventional on-bore sights to off-bore sights.

2 Aim

The aim of this laboratory study was to assess the capabilities of off-bore sights for target detection, engagement, accuracy and efficiency compared to traditional on-bore sights. The goals included

a. Quantifying the performance of an unmagnified Land Warrior DVS off-bore sight, iron sight, optically magnified sight (Elcan C79) and a prototype magnified off-bore sight (DCIEM Gunsight) for briefly exposed static and moving targets in a small arms simulator; and

b. Qualifying the soldier acceptance of an unmagnified Land Warrior DVS off-bore sight, iron sight, optically magnified sight (Elcan C79) and a prototype magnified off-bore sight (DCIEM Gunsight) in a small arms simulator.

3 Method

The following description provides a general overview of the assessed systems and approach. Further details are provided in subsequent sections.

3.1 Overview

A six-day laboratory trial was undertaken at the Defence and Civil Institute of Environmental Medicine (DCIEM) in Toronto, Ontario from September 21 to September 28, 2001. Twelve volunteer militia infantrymen completed a standardized Small Arms Trainer (SAT) simulator marksmanship test while using off-bore HMS or standard on-bore sights. The tests included assessments in the supported and unsupported prone and standing positions with either static or dynamic targets in a repeated measures design.

The FATS inc. Small Arms Trainer (SAT) IV was used for data collection. During each test, the presentation of conditions was balanced to minimize order effects amongst participants. Human factors (HF) tests included assessments of rifle firing performance, compatibility, user acceptance, and criteria of importance. Assessments of rifle firing performance included targets missed, targets hit, total shots fired, the distance, location and speed of hit, missed targets, shooting precision and aiming time.

Data collection included questionnaires, focus groups, performance measures and HF observer assessments as well as the automatic data collection capabilities of the SAT simulator computers.

3.2 Sight Systems

A description of the on-bore and off-bore sighting systems assessed in this trial is detailed below.

3.2.1 U.S. Land Warrior System (v. 0.6)

The United States Army has developed their Land Warrior System to increase lethality and survivability in the 21st century soldier. The components of this system that we examined were the Digital Video Sight in combination with the HMD, and their capabilities for off-bore firing. The Land Warrior Systems that we received were version 0.6, which came with an unmagnified Video Sight and automatic white balance control (see Figure 3). White balance adjusts the digital sight's exposure so that the image presented to the wearer has the same colour cast no mater what light source is utilized.

Figure 3: The U.S. Land Warrior system (v. 0.6)

3.2.1.1 Daylight Video Sight

Kaiser Electronics' Daylight Video Sight (DVS) is a Commercial-Off-The-Shelf (COTS) Design, which has been ruggedized to meet the requirements of the US Land Warrior System (see Figure 4).

Figure 4: Weapon Mounted Daylight Video Sight (Front)

The DVS is a full colour, SVGA (525 Lines High Resolution TV imagery) miniaturized video camera that is used in conjunction with a Helmet Mounted Display (HMD) to give the soldier firing power from behind cover without having to expose his torso and head. The DVS has been demonstrated to perform consistently after weapon firing.

The Land Warrior DVS has an automatic 'iris'. It permits varying degrees of light through, depending on the brightness at the center of the area of focus. The reticle on the DVS appears as an overlay on the video image. It accomplishes this by utilizing the text-on-screen function of the onboard computer. It adopts the plus character, "+". The reticle could either be used as a cross hair, with the point-of-aim in the center, or with the point-of-aim at the top of the vertical post. Due to cable interference, weaver rails could not be permanently attached to the SAT weapons. Instead, the rails were securely attached using "Gun Tape". The DVS was then attached to the side rail.

The Land Warrior Digital Video Sight has the following specifications:

Magnification	1X
Resolution	SVGA, 525 Lines Hi-res TV

3.2.1.2 Helmet Mounted Display

The monocular Helmet Mounted Display (HMD) included in the US Land Warrior system allows the unaided eye access to the environment and unhindered dark adaptation. It is a slide-up design and is compatible with ballistic eyewear and spectacles (see Figure 5).

Figure 5: US Land Warrior Helmet Mounted Display

It accommodates a large focus range and weighs only 3.5 ounces. It can be attached to the helmet to cover either the right or the left eye, and is connected to the DVS via a Ruggedized cable. The HMD is an AMEL (Active Matrix Electro Luminescent) flat panel display providing VGA (640 X 480 pixel) resolution and has a 40-degree field of view.

The Land Warrior HMD has the following specifications:

Weight	90 g (3.5 ounces)
Display Type	Colour AMEL (Active Matrix Electro Luminescent)
Resolution	VGA, (640 X 480 pixels)
Field of View	40°
Connection	VGA, USB

3.2.2 DCIEM Helmet Mounted Gunsight

The DCIEM Helmet-Mounted Gunsight is a prototype off-bore system developed and constructed at the Canadian Defense and Civil Institute of Environmental Medicine (DCIEM). The system is made from Commercial-Off-The-Shelf (COTS) components. The Helmet-Mounted Gunsight is comprised of three components; the DCIEM Video Sight, the Virtual Vision Sport HMD, and a power and connection box that is worn strapped to the shoulder (see Figure 6).

Figure 6: The DCIEM Helmet Mounted Gunsight

Field-testing has demonstrated that the Camera and HMD combination used in this system does not flicker or change in brightness during or after live firing while attached to a rifle (Reference J). This system was built for experimental purposes only, and was meant to be a prototype for a weapon system that may eventually be ruggedized and deployed in the field.

3.2.2.1 DCIEM Video Sight

The DCIEM Video Sight is made from commercial off-the-shelf equipment. A commercial Panasonic Video Camera was mounted to an electrically controlled optical zoom lens (see Figure 7).

Figure 7: DCIEM Video Sight (Front)

The video sight is attached to an adjustable optical zoom that can magnify the target up to 3.4 times. For the purposes of this study, the DCIEM video sight was used at full zoom (3.4x) during all tests. The sight is adjustable for depth of magnification (1-3.4x), focus, and white balance ("iris"), all of which can be controlled manually by switches mounted on the sight itself (see Figure 8).

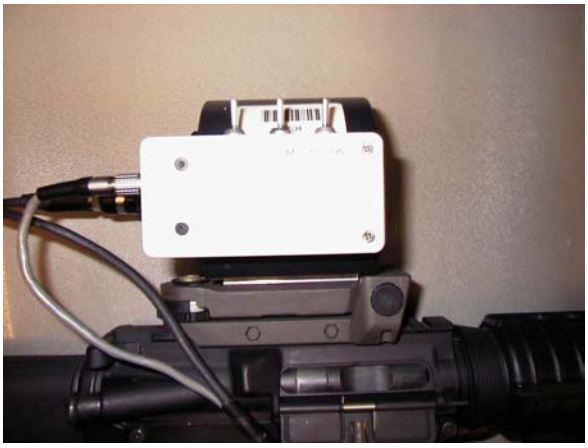

Figure 8: DCIEM Video Sight controls

The reticle that overlays the video picture, is produced by the text-on-screen feature of the camcorder component. In this case, the reticle was produced by two underscore characters, a space, a period, a space and another two underscores ("__ . __"). The period is used as the point of aim.

3.2.2.2 Virtual Vision Sport HMD

The Head-Mounted Display used in the DCIEM system is the commercially available Virtual Vision Sport HMD by Virtual Vision (see Figure 9).

Figure 9: Virtual Vision Sport HMD (Left-eye version)

The HMD consists of a see-through visor with a reflected LCD screen visible to one eye. Two versions of the Head Mounted Display were available for left-eye and right-eye dominant participants.

The Virtual Vision Sport HMD has the following specifications:

Weight	150 g (5.3 ounces)
Display Type	Active Matrix Colour LCD
Resolution	360 X 260 pixels
Field of View	17.5° X 13.6°

3.2.3 Iron Sight

The Canadian Land Forces employ C7 and C7A1 rifles. The C7A1 is a converted C7 rifle, which has had its upper receiver modified to accept a weaver rail. While the rear aperture of the C7 rifle is machined off on the C7A1, the front post sight is not modified. Although most Land Force units use the Elcan sight with the C7A1 rifle, a number of back-up iron sights have also been introduced. The back-up sight replaces the removed rear aperture sight (see Figure 10).

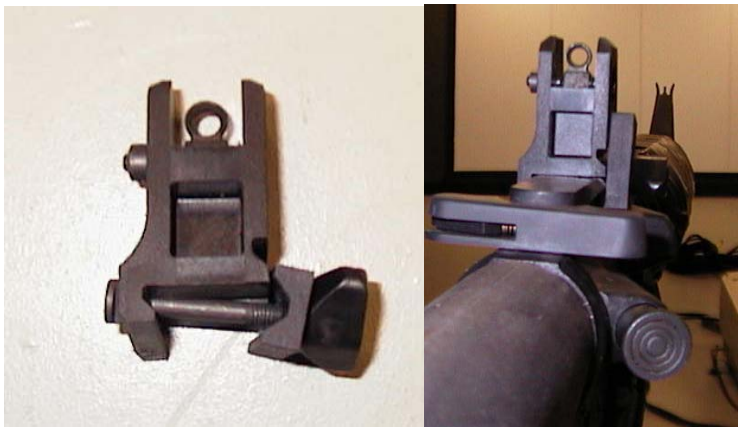

Figure 10: Iron sight for C7A1

In combination with the sighting post at the end of the C7A1's barrel, the Iron sight provides a rapid method of acquiring close targets without imposing the restricted field of view associated with optical or video sights. Further, it holds its zero well. In previous studies, the Iron sight has been shown to be very effective for close-combat engagements (Angel & Massel, 2001). Another benefit of the Iron sight is soldiers' general familiarity with it.

3.2.4 C79 Optical Sight

The Elcan C79 optical sight is the standard optical sight for the Canadian Army. It is a waterproof, ruggedized 3.4x magnification sight with shockproof optics and an adjustable base. The aiming reticle in the C79 sight, used in this experiment, was a black vertical post. Although the sight provides magnification it does restrict the field-of-view - see Figure 11.

Figure 11: Elcan C79 Optical Sight

The C79 Optical Sight has the following specifications:

Weight	0.7 kg (1.5 lb)
Magnification	3.4x standard
Field of View	8°

3.3 Trial Conditions

The laboratory trial included four sight conditions, two postural conditions, and two target conditions. The Land Warrior, C79, and the Iron sights were evaluated in a complete repeated measures design. Tests with these three sights included the following: two postural conditions, prone and standing positions; and the two target conditions, static/gallery range and dynamic/moving targets.

In addition to the Land Warrior, C79 and the Iron sights, every subject also completed the static/gallery range scenario in the standing position with a fourth sight: the DCIEM Helmet Mounted Gunsight at full zoom (3.4x). Tests with the DCIEM sight included the gallery range scenario in the standing position, shooting precision (shot group size) in both the standing and prone postures, and a test for aim time was done in the standing posture.

The trial was conducted at DCIEM in Toronto, Ontario, using the FATS inc. Small-Arms Trainer (SAT) shooting simulator with randomized static/gallery range computer generated ("Lane") scenarios and dynamic /moving target ("CGI") scenarios.

A within subject repeated measures design was used to evaluate all the weapon sights. The order of presentation was counterbalanced to minimize order effects of learning or fatigue.

3.3.1 Static Target Conditions

In the static/gallery range scenarios, 32 infantry-style computer generated targets were programmed to randomly pop-up for three seconds on a bitmap of a conventional gallery range over the course of five minutes. The targets were evenly distributed over eight horizontal locations and programmed distances of 50m, 75m, 100m, and 150m within a lane. There were a total of seven static sight-posture conditions, which included the following:

- Static – Land Warrior, Prone/Supported
- Static – Land Warrior, Standing/Unsupported
- Static – C79 (Optical) Sight, Prone/Supported
- Static – C79 (Optical) Sight, Standing/Unsupported
- Static – Iron Sight, Prone/Supported
- Static – Iron Sight, Standing/Unsupported
- Static – DCIEM off-bore Sight, Standing/Unsupported

3.3.2 Dynamic Target Conditions

The purpose of the dynamic target test was to develop a rigorous set of data for target engagement performance for transient, moving targets, as they may represent a more realistic combat situation. Twenty (20) targets were programmed to randomly move across a computer generated village street over a period of five minutes. Half the targets moved across the screen at a "walking" speed, and the other half at a "running" speed. Also, half of the targets were between 30m to 50m, and the other half 50m to 80m (the targets subtended approximately 0.9º at 30m and 0.3° at 80 m). The targets moved across the screen evenly distributed between left-entry/right-exit and right-entry/left-exit locations. There were a total of seven dynamic sight-posture conditions, which included the following:

- Dynamic – Land Warrior, Prone/Supported
- Dynamic – Land Warrior, Standing/Unsupported
- Dynamic – C79 (Optical) Sight, Prone/Supported
- Dynamic – C79 (Optical) Sight, Standing/Unsupported
- Dynamic – Iron Sight, Prone/Supported
- Dynamic – Iron Sight, Standing/Unsupported

Table 1 shows both static and dynamic target conditions.

Table 1: Trial Conditions – Static and Dynamic Scenarios

Targets →		**Static (Gallery Range)**				**Dynamic (Moving)**			
Posture ↓	*Sight →*	**LW**	**C79**	**Iron**	**DCIEM**	**LW**	**C79**	**Iron**	**DCIEM**
Prone, Supported		12	12	12	-	12	12	12	-
Standing, Unsupported		12	12	12	12	12	12	12	-

Note: N = 12 participants

3.3.3 Aim Time

The purpose of measuring aim time was to log the speed at which participants could accurately acquire a good sight picture, and then compare these times for the various sights. It was measured in the standing position. To begin, participants faced away from the screen. On the experimenter's command, the participant turned around and quickly fired five aimed shots at the target. The time between turning around and the first shot that hit the target was measured by the experimenters. There were a total of four shooting precision conditions, which included the following:

- Aim Time – Land Warrior
- Aim Time – C79 (Optical) Sight
- Aim Time – Iron Sight
- Aim Time – DCIEM off-bore Sight

3.3.4 Shot Groupings

Consistency of lay or group size is a typical measure of shooting accuracy. There are a number of approaches to determine group size: maximum spread between the every shot (five or 10 rounds) or the best four of five shots etc. Precision can also be assessed by the average group radius. It is the average difference between individual shots and the group centroid.

Shot group sizes were measured to provide a measure of accuracy and consistency of aim point for each sight. Shot groupings scores were automatically collected by the SAT computer. Participants were required to fire five rounds in their own time at the center of a fixed target. Shot groupings

were measured in prone and standing postures. There were a total of seven shot grouping sight-posture conditions, which included the following:

- Shot Groupings – Land Warrior, Prone/Supported
- Shot Groupings – Land Warrior, Standing/Unsupported
- Shot Groupings – C79 (Optical) Sight, Prone/Supported
- Shot Groupings – C79 (Optical) Sight, Standing/Unsupported
- Shot Groupings – Iron Sight, Prone/Supported
- Shot Groupings – Iron Sight, Standing/Unsupported
- Shot Groupings – DCIEM off-bore Sight, Standing/Unsupported

Table 2 shows aim time and shooting precision conditions.

Table 2: Trial Conditions – Aim Time and Shooting Precision

Sight	LW	C79	Iron	DCIEM
Aim Time	12	12	12	12
Shooting Precision – Prone, Supported	12	12	12	-
Shooting Precision- Standing, Unsupported	12	12	12	12

Note: N = 12 participants

3.4 Trial Participants

Twelve Canadian Forces (CF) infantry militia volunteers were recruited for this study. They consisted of six privates and six corporals. Participants were screened with Snellen vision and near-vision tests. Participants had a minimum of 6/6 corrected vision. The participants included a significant number of soldiers who had experience with both the C7A1's sight as well as the C79 optic sight, and thus only required familiarization time with the Land Warrior and DCIEM off-bore sights.

3.5 Quantitative Data

Quantitative data collection focused on HF criteria, such as visual acuity and rifle firing performance (i.e., accuracy, number of shots fired, shot groupings, and aim time).

3.5.1 Visual Acuity

Prior to engaging in the simulation, participants were screened for visual acuity. A Snellen chart mounted on a well-lit office wall was used to test participants for visual acuity. Eight of the 12 participants had 6/6 vision (corrected) while three had 6/6 in one eye and no worse than 6/9 in the other. Only one participant had 6/9 vision in both eyes. Near-vision was also tested using a standard near distance measuring card. All participants passed the screening level (n=5).

3.5.2 Rifle Firing Performance

3.5.2.1 Accuracy

Rifle firing accuracy was recorded for each SAT session. Overall accuracy (targets displayed/targets hit) was recorded by the SAT computer. Targets were set such that one hit marked the target as killed. Accuracy was also assessed by distance and, for the static target condition, the eccentricity from the centre of the lane.

3.5.2.2 Number of Rounds Fired

The number of rounds fired was recorded automatically via the SAT system. The number of shots fired versus the number of shots hit provided a measure of firing efficiency.

3.5.2.3 Shot Groupings

The participants had their shot grouping sizes measured by the SAT computer in the standing and prone positions with each sight condition (except for the DCIEM off-bore sight which was only measured in the standing position). The FATS Inc. system uses the maximum spread/group diameter method, which calculates the distance between the two most widely dispersed shots in a group of five. The average diameter of two groupings was used in the analysis for each posture.

3.5.2.4 Aim Time

The time to acquire and hit a target was also measured for each sight in the standing position. The participants stood with their backs to the simulator screen in a standing ready position. Upon a signal from the experimenter, the participants turned around and fired at the target.

Although the time to turn and fire a round in the general direction of a target may be an indication of the time to suppress a target, it may not be an accurate measure of precise aiming time. Thus, the time between the signal and the first shot to hit the target was captured in order to insure that accurate aim time was recorded. Participant had to hit the target within three rounds for the timing to be valid.

3.6 Qualitative Data

3.6.1 Compatibility and Task Acceptance:

The Task/Compatibility Questionnaire measured participants' overall acceptance of each sight for the optical performance, functionality, task demands, compatibility and overall acceptance criteria (see Annex A). Participants rated their acceptance level on a seven point Likert scale, where one equaled "Completely Unacceptable" and seven equaled "Completely Acceptable" (see Figure 12).

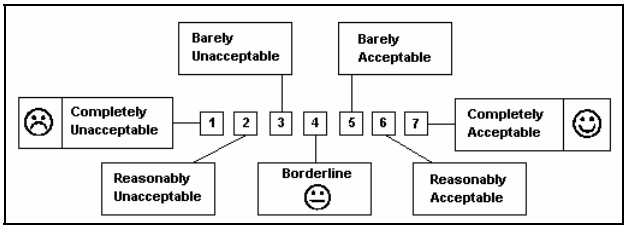

Figure 12: Standard rating scale

3.6.2 Criteria of Importance

Following the completion of the target engagement assessment serials, users completed a Criteria of Importance Questionnaire (see Annex B) for functionality, physical demands, compatibility, optics, and task performance. Participants rated Criteria of Importance on a seven point scale, where one equaled "Of No Importance" and seven equaled "Extremely Important".

3.7 Statistical Analysis

A mixed block repeated measures analyses of variance, for sight system and firing posture effects, were undertaken for all individual task acceptance questions and objective performance results. Post hoc analyses consisted of Duncan's critical range tests. Where appropriate, Mauchly's test of sphericity was performed and Greenhouse-Geisser, Huynh-Feldt and Lower-Bound correction factors were applied. Differences were identified at $p<.05$.

3.7.1 Statistical Comparisons

The comparisons in this trial included the following:

Measure	Method	Analysis
Comparing sight performance in the prone position against static pop-up targets	Objective assessment by recording number of hits	ANOVA between: Conditions (2): • Sights x 4 • Target distance (4)
Comparing sight performance in the standing position against static pop-up targets	Objective assessment by recording number of hits and rounds fired	ANOVA between: Conditions (2): • Sights x 3 • Target distance (4)
Comparing lane effects	Objective assessment by recording number of hits	ANOVA between: Conditions (1): • Lane position (8)
Comparing sight performance against moving targets in an urban CGI scenario	Objective assessment by recording number of hits	ANOVA between: Conditions (3): • Sights (4) • Target speed (2) • Target distance (2)
Comparing sight performance for consistency of lay	Objective assessment by recording grouping size – (average of two groupings).	ANOVA between: Conditions (2): • Sights (4)

		• Posture (2)
Comparing sight performance for speed of aiming	Objective assessment by recording number time to first hit	ANOVA between: Conditions (1): • Sights (4)
Comparing individual statement's ratings of different sight acceptance ratings	Subjective assessment by participant	ANOVA between: • 32 individual questions Conditions (1): • Sights (4)
Comparing individual statement's ratings of the importance of sight design criteria	Subjective assessment by participant	Descriptive: • Design importance criteria (38)

4 Procedures

4.1 Setup

The FATS inc. Small Arms Trainer (SAT) IV was used for data collection. It is a weapon engagement simulator that includes two controlling computers, a dynamic video projector, a large screen 20 feet in front of the firing platform, and realistic C7A1s with full sound and recoil effects linked to the computer via cabling. Performance on small-arms simulation trainers is positively correlated with performance in a live firing range (References E-F and L).

The SAT simulator at DCIEM was located in a dedicated room. The configuration used in this trial was for two vice four simultaneous shooters. Wooden ramps were constructed, fitted with padding, and topped with a low wall of sandbags for a comfortable prone firing position (see Figure 13).

Figure 13: The SAT room setup

Each day, the SAT system would be booted up and the compressed gas turned on (for recoil effects). The weapons were registered with the SAT computers, tested, and prepared for use.

4.2 Preliminary

At the beginning of the trial, participants were introduced to the trial team, briefed on the purpose of the experiment, the trial schedule, and the data collection methods (questionnaires, focus groups, firing accuracy etc.). The questionnaire briefings explained the standard rating scale, the data scoring methods, and the rules of questionnaire completion. The sight, posture, and target order conditions were introduced. Participants were provided with a thorough briefing on the DCIEM

off-bore system and the SAT simulator. A representative from the United States Army Soldier Systems Directorate briefed the participants on the Land Warrior system and provided expert support throughout the trial. Participants then had the opportunity for two days of practice shooting on the SAT, using on-bore and off-bore sights, to become comfortable with the latter. Not surprisingly, engaging targets with the weapon held at the hip or off the shoulder was very unusual to the participants.

4.3 Testing Procedures

Before beginning each trial scenario, the participants would bore-sight the SAT C7A1 so that the reticle of the sighting system was in accordance with their SAT weapon's point of aim. Using the SAT screen at 20 feet, participants fired at a target or cross-hair on the screen. The SAT computer could then automatically zero the weapon. This procedure was repeated until the shooter and the test staff was happy with the collimation. The participants were issued sights according to the matrix shown in table 3. (The sight assessment order was not perfectly balanced because of a delay in receiving replacement modules for defective Land Warrior systems. Thus, the Land Warrior was not available on the first day of the trial.)

Table 3: Order of conditions

Participant	Condition 1	Condition 2	Condition 3
1	Iron	C79	Land Warrior
2	Iron	C79	Land Warrior
3	Iron	Land Warrior	C79
4	Land Warrior	Iron	C79
5	C79	Iron	Land Warrior
6	C79	Iron	Land Warrior
7	C79	Land Warrior	Iron
8	C79	Land Warrior	Iron
9	Land Warrior	Iron	C79
10	Land Warrior	Iron	C79
11	C79	Land Warrior	Iron
12	C79	Land Warrior	Iron

The sights were assessed from both a standing and a prone position in the gallery range/static scenario and from both postures in the dynamic/moving target scenario for a total of four tests each condition. For the DCIEM off-bore sight, there was no balancing of orders, since all participants performed the firing test after the other conditions were completed and only the standing, static scenario was tested.

Participants were informed of the order of use for the test conditions, and started at either the standing or prone posture. Two shot group sizes were recorded immediately after participants zeroed their sights, and again when they switched posture.

Participants had their aim time measured immediately after their shot groupings were recorded. Participants were asked to face away from the screen, and then timed from the moment of turning

around to the first shot that hit the target. The participants could fire up to five shots. The times of the first hit were recorded by stopwatch.

After the aim time test was complete, participants moved on to the static/gallery range test or the dynamic/moving target test scenarios. In the static/gallery range test, participants were advised that the scenario would last 5 minutes, include approximately 30 targets and that the targets would be up for two seconds each. As well, they were told that the targets would drop if hit. Participants were asked to engage each target with aimed single shots only.

Figure 14 shows a participant completing the static/gallery range scenario in the standing position.

Figure 14: Static/gallery range scenario (standing)

For the dynamic/moving target scenarios, the participants were told that the scenario would last 5 minutes and include approximately 20 moving targets, either ”walking” or “running”. Experimenters explained the length of the computer generated street to help participants infer target speed. They were also told that the targets would drop if hit. As with the static/gallery range test, the soldiers were asked to engage the targets with aimed single shots only. Upon completion of the two (standing and prone) static scenarios and two dynamic scenarios, participants were given compatibility and task acceptance exit questionnaires for the sight they had just used.

The rifle firing performance was recovered from the SAT log, and timing data was recorded from digital stopwatches. For the static scenarios, targets hit at each distance and eccentricity from centre was recorded. For the dynamic targets, hit at near and far distances and each speed were recorded. Experimenters also noted any irregularities in the performance of the scenario, such as the number of stoppages that each participant encountered. This general test procedure was followed each day for the 12 test participants for each condition.

Upon completion of the assigned conditions, the participants each completed an exit Criteria of Importance Questionnaire and engaged in a focus group discussing their overall comments with the experimenters.

5 Results

5.1 Objective Results

Objective data collected included hit results, aim time and shot grouping measurements from both the static/gallery range and the dynamic/moving target scenarios. Time limitations prevented testing all sights in all conditions. As such, as the most challenging of the four, the DCIEM Helmet-Mounted Gunsight was only tested in the static/gallery range scenario. In order to include the DCIEM off-bore sight in the analysis, special attention has been paid to the static, standing condition.

5.2 Static / Gallery Range Scenarios

The performance of the different sights in the different postures was analyzed. Within the static scenario data, the hits were recorded for each target distance of 50m, 75m, 100m, and 150m, as well as for location of targets relative to the centre of the lane.

5.2.1 Prone Posture – Accuracy by Target Distance

The percentage of targets hit by distance in the static target/gallery range scenarios in the prone firing position is shown in Figure 15 for the Iron, C79, and Land Warrior sights. As noted earlier, the DCIEM off-bore sight was not tested in the prone position due to time constraints. Overall, less than 65% of the targets were hit in the prone position, and as displayed below in Figure 15 the percentage of targets hit significantly decreased as the target distance increased.

There were significant differences between the performances of the sights in the prone firing position and the overall results by range bands. The C79 sight performed significantly better than the Land warrior DVS $F(2, 22)=4.38$, $MS=401.3$, $p=.025$.

The results for all the sights varied significantly by range band, i.e. more hits were recorded at 50m, than 75m, more hits at 75m than 100m etc $F(3, 33)=62.43$, $MS=13100$, $p=.00$.

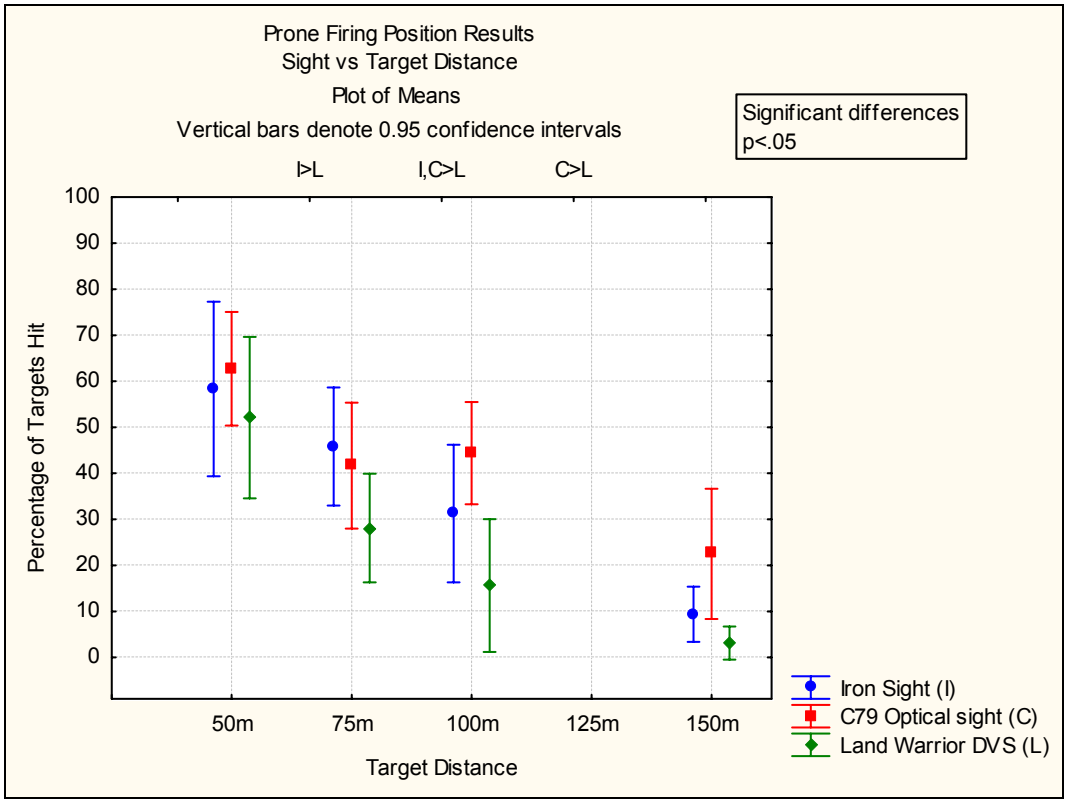

Figure 15: Percentage of targets hit by distance in the prone firing position

There were no significant differences among the sights for targets at a range of 50m. At 75m, the Iron sight was better at hitting targets than the Land Warrior. By 100m, targets were significantly harder to hit with the Land Warrior than with either iron or C79 sights. At 150m, the performance of the Iron sight was no longer significantly better than the Land Warrior, but the magnified C79 was still hitting significantly more targets than the unmagnified Land Warrior off-bore sight.

5.2.2 Standing Posture – Accuracy by Target Distance

The percentage of targets hit by distance in the static target/gallery range scenarios in the standing firing position is shown in Figure 16 for the Iron, C79, Land Warrior and DCIEM sights. In the standing firing position, participants were instructed to shoot in the most comfortable position for them. The majority of the participants shot from the hip when using the Land Warrior or DCIEM sight. Overall, the percentage of targets hit significantly decreased as the target distance increased (except between 75m and 100m targets).

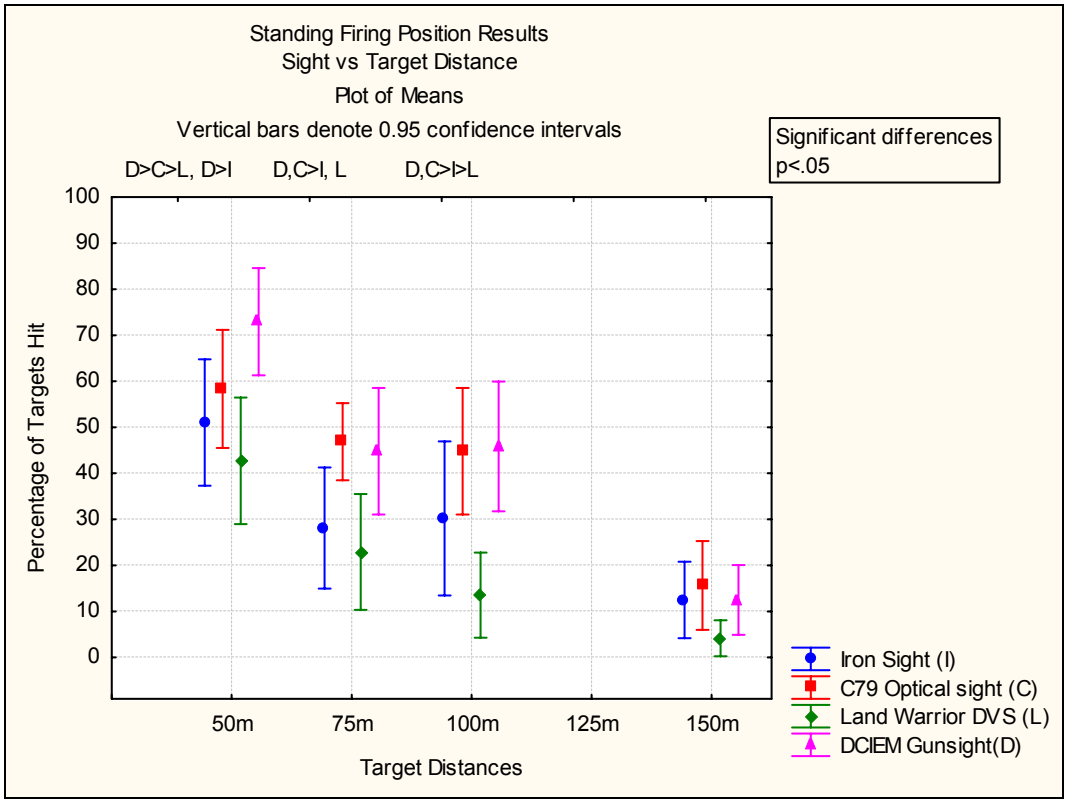

Figure 16: Percentage of targets hit by distance in the standing firing position

There were significant differences between the performances of the sights in the standing firing position and the overall results by range bands. The DCIEM Gunsight and the C79 optical sight performed significantly better than the Land Warrior DVS and the Iron sight F(3, 33)=9.33, MS=583.00.3, p=.00.

The results for all the sights varied significantly by range band F(3, 33)=72.21, MS=225.50, p=.00. Significantly more hits were recoded at 50m than 75 or 100m. More hits were recorded at 75 and 100m than 150m. There were no significant differences in the number of hits between 75 and 100m.

From 50m, participants hit significantly more targets using the DCIEM off-bore sight than any other sight. The C79 also outperformed the Land Warrior at this distance. At 75m, significantly more targets were hit with both the magnified C79 and DCIEM sights than with either of the unmagnified Iron and Land Warrior sights. This trend continued at a distance of 100m, except that the Land Warrior began to perform significantly worse than the Iron sight. From 150m, however, no significant differences were found between any of the sights in the standing position, magnified or non-magnified.

5.2.3 Engagement Performance by Posture

The performance of the iron sight, C79 optical sight and the Land warrior DVS in prone and standing positions were examined to see if there was a posture effect. While performance slightly

improved in the prone position for all sights the differences were not significant F(2,22)=.24, MS=113, p=.785.

5.2.2.1 Standing posture - Shots fired per hit

The total shots fired were divided by the number of targets hit for each sight, producing a measure of shots fired per hit. Fewer shots per hit could indicate a greater efficiency for the sight. The total number of rounds fired in the static/gallery range test was analyzed to identify which systems were more efficient. The mean shots fired per hit for each sight are shown in Figure 17. The mean shots per hit for each sight are as follows: 4.7, 2.6, 6.5, and 2.5 for the Iron, C79, Land Warrior, and DCIEM sights respectively.

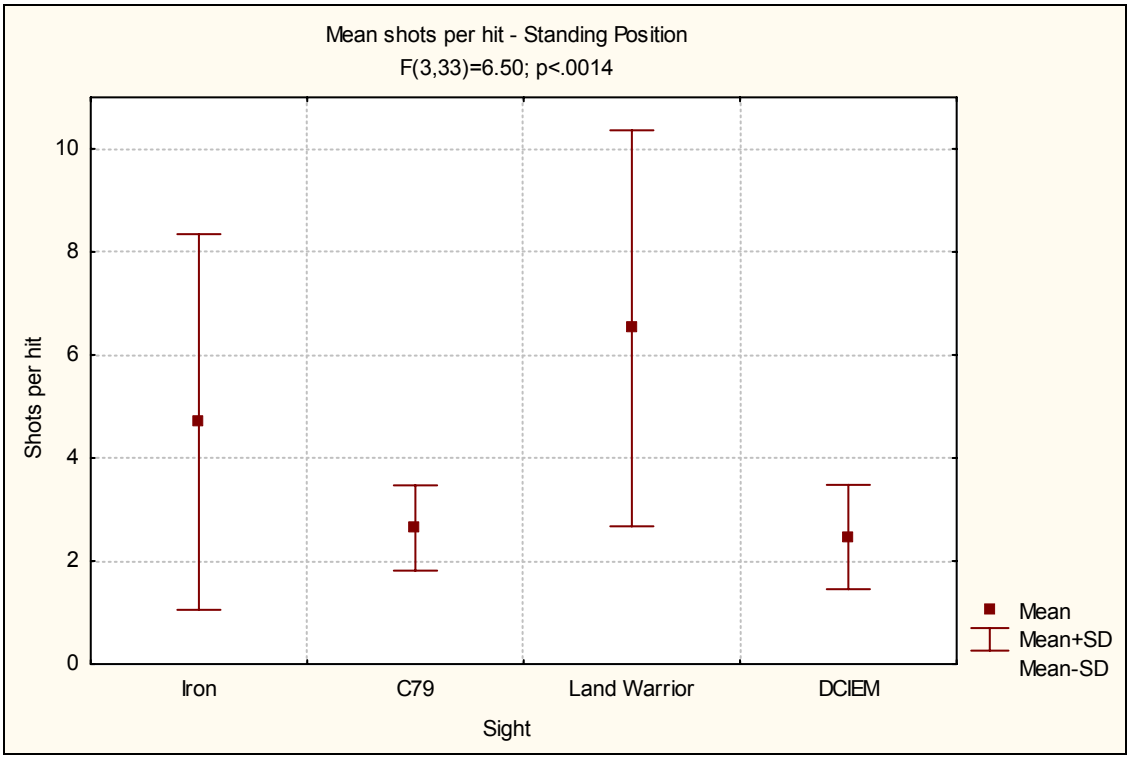

Figure 17: Shots fired per hit in the standing posture

There were significantly more shots fired per hit using the Land Warrior compared to the C79 and DCIEM sights. [5]

5.2.2.2 Accuracy by Azimuth Location of Targets

The static/gallery range scenarios used in this study had targets popping up in eight different azimuth locations within the range (the range was divided into eight equally spaced lanes ~ 3° of viewing angle). Targets were positioned on the far left (3-L), far right (3-R), mid left (2-L), mid

[5] In the prone position (not shown in Figure 17), the Iron, C79, and Land Warrior sights had mean shots per hit of 3.7, 2.4 and 7.3 respectively. In the prone position, the Land Warrior required significantly ($p < .05$) more shots per hit than the C79 sight.

right (2-R), slightly left (1-L), slightly right (1-R) and in the center (L-0 and R-0). The range in the scenarios was very narrow and thus was more of a target engagement task than a target searching task. While it was believed prior to the start of the experiment that the percentage of targets hit would not differ by lateral location, such was not the case. Preliminary inspection of the results revealed a trend in that targets on the far left hand side of the range were not hit as often as those in the center or right of the range. Given this apparent effect the percentage of targets hit by location in the range was examined. Across all ranges and sights accuracy varied from l<30% in lane 2-L to >35% in lanes 0-L and 2-R - see Figure 18. Engagement accuracy (for both standing and prone engagements) was significantly dependent on target location- $F(7,987)=12.6$, $MS=4.7$, $p=0.0$. Mauchly's test of sphericity was significant so Greenhouse-Geisser, Huynh-Feldt and Lower-Bound correction factors were applied. The results still indicated that there were significant differences in accuracy between lane positions. Lane 3-L and 2-L had significantly fewer hits than the rest of the range, and lane 1-L had significantly fewer hits than the center lanes and two of the right hand lanes (R-1 and R-3).

Less than 30% of the targets were hit when participants used the Land Warrior, less than 45% of the targets were hit with the C79 optical sights and less than 35% of the targets were hit with the iron sight. While there was no significant difference in the percentage of targets hit across the eight lateral locations for the Land warrior DVS, there were significant differences for the C79 and iron sights. When participants used either the C79 or Iron sights, targets popping up on the left side of the lane were missed significantly more often than the targets popping up in the center or right side of the lane – see Figure 18.

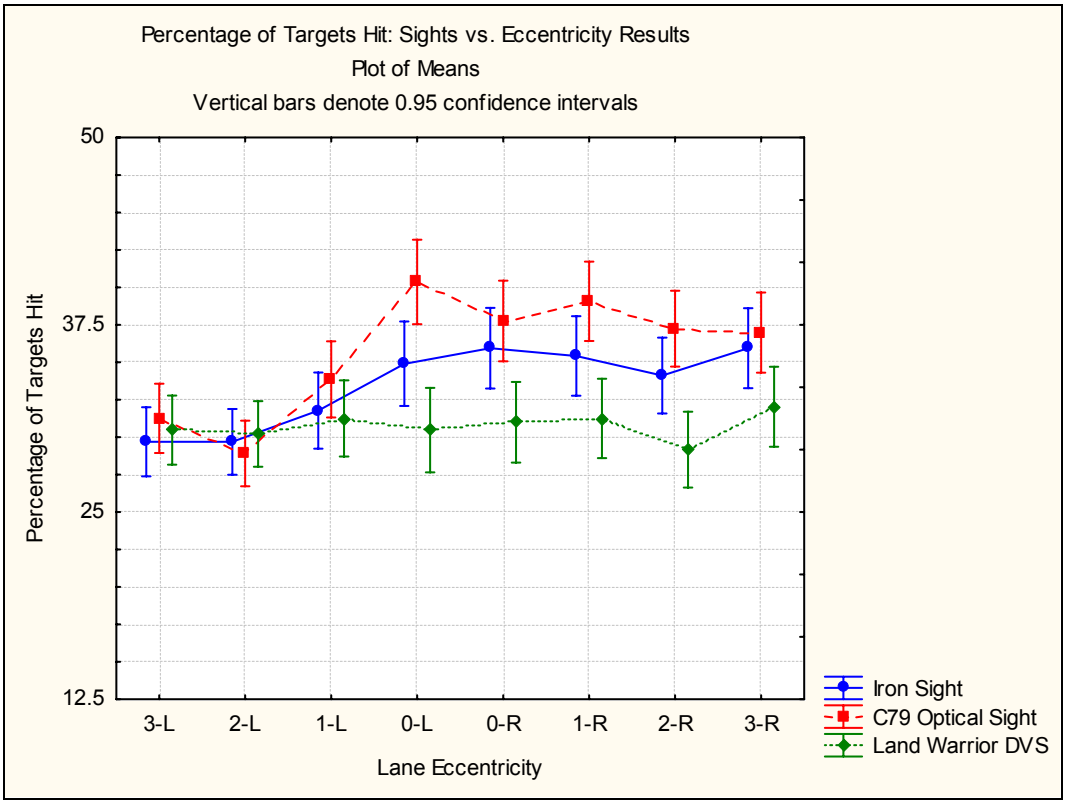

Figure 18: Percentage of targets hit at lateral location in lane

Soldiers using the Iron and C79 sights hit significantly lower numbers of targets at the 3-L and 2-L lateral locations compared to the 0-L, 0-R, 1-R, 2-R, 3-R lateral locations. Soldiers using the Iron and C79 sights hit significantly fewer targets at the1-L lateral location than at the 0-R lateral position.

It is believed that the lane effect witnessed may be dependent on subject sighting behaviours. All of the participants were right handed and shot using their right eye as the master eye. Given that many shooters are taught to close the disengaged eye, it may be possible that many subjects did not see targets (as fast) on the left hand side of the range when using the iron sight or optical sight (subject's were only using the right eye to search and thus half the range was hidden). This effect would not have been witnessed with the use of a relaxed sight like the Land warrior DVS and the results support this contention.

5.2.3 Dynamic / Moving Target Scenarios

Sights were assessed on a number of criteria for the dynamic scenarios. Measures included the number of rounds fired per target; the number of hits with targets at both near (30-50m) and far (50-70m) distances, and the number of hits with targets moving at fast or slow speeds.

5.2.3.1 Accuracy by Target Distance and Speed of Movement

At near distances and with walking targets, engagement accuracy for the three sights varied from a high of 95% for the C79 sight to a low of 80% for the Land Warrior system. With running targets, accuracy dropped off to just 47% for the Iron sight and just 38% for the Land warrior system.

At far distances, engagement accuracy with walking targets varied from a high of 95% for the C79 sight to a low of 56% for the Land warrior system. With running targets, accuracy dropped off to just 50% for the C79 sight and just 28% for the Land Warrior system (see Figure 19).

Engagement accuracy varied significantly between sights $F(2, 22) = 8.358$, $MS= 10870$, $p= .001$. The Iron sight and C79 sights hit significantly more targets than the Land Warrior DVS. Significantly more walking targets were hit than running targets (83 % vs. 42%)- $F(1, 11)=112.7$, $MS= 123270$, $p=0.00$. Significant differences in hit accuracy for near and far targets were only obtained at the $p= .06$ level – $F(1,11) = 4.17$, $MS=2558$, $p=.06$. Interactions between sight, target speed or target distance were significant.

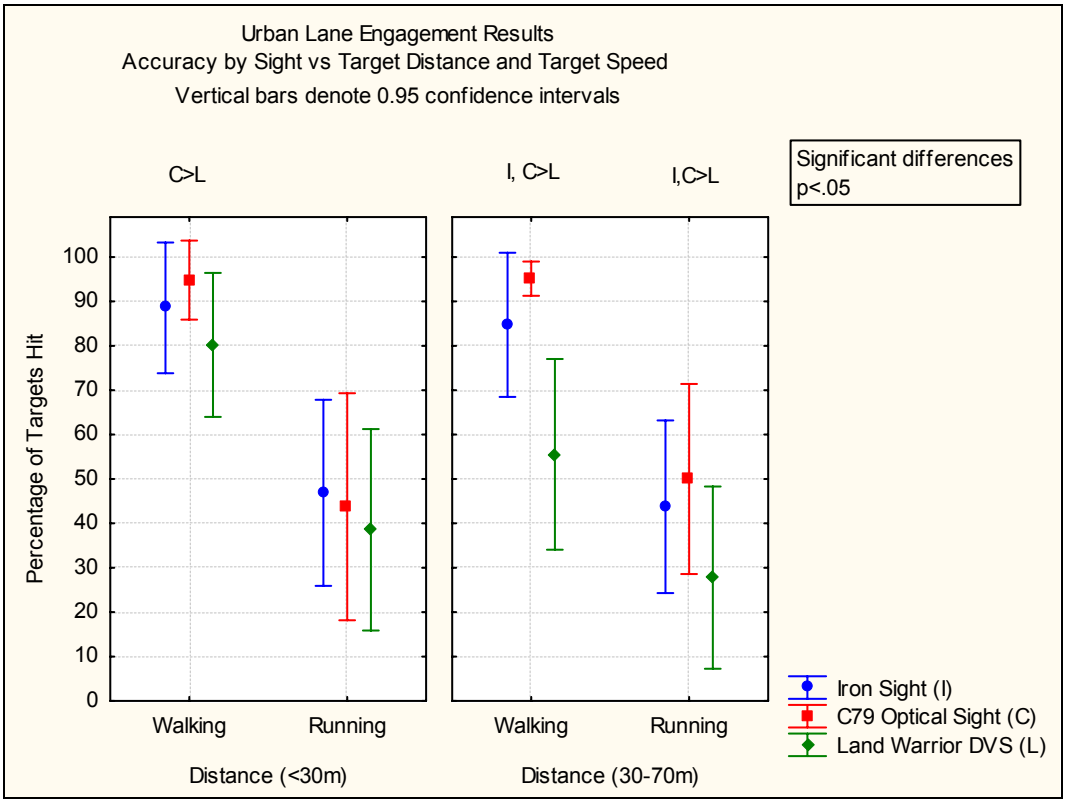

Figure 19: Percentage of targets hit by distance and speed

Engagement accuracy was higher with the C79 and Iron sight than with the Land Warrior sight in the CGI urban engagement scenarios. The participants were significantly less successful engaging running targets than walking targets at all ranges. The Land warrior sight was notably less accurate for further targets even when they were walking.

5.2.3.2 Shots Fired by Target Distance and Speed of Movement

The number of shots per hit for the three sights in the near distance varied from a mean high of 3.4 for the Land Warrior system to 2.0 for the Iron and C79 sights with walking targets. If the targets were running, the mean average number of rounds per hit for the Land Warrior became 2.9, for the C79 it became 2.8, and for the Iron 3.1. The results are shown in Figure 20.

The number of shots fired per hit varied significantly between the three sights $F(2,22)=17.09$, $MS=45.3$, $p=.00$. The Land Warrior DVS required more shots on average (2.6) to register a hit than the iron (1.6) or the C79 sight (1.3). Significant differences in shots fired per hit for near and far targets were only obtained at the $p= .07$ level – $F(1,11) = 3.86$, $MS=28$, $p=.076$. More shots were required on average for longer range targets (1.9) than for shorter range targets (1.7).

Interactions between sight & target speed and sight & target distance were significant.

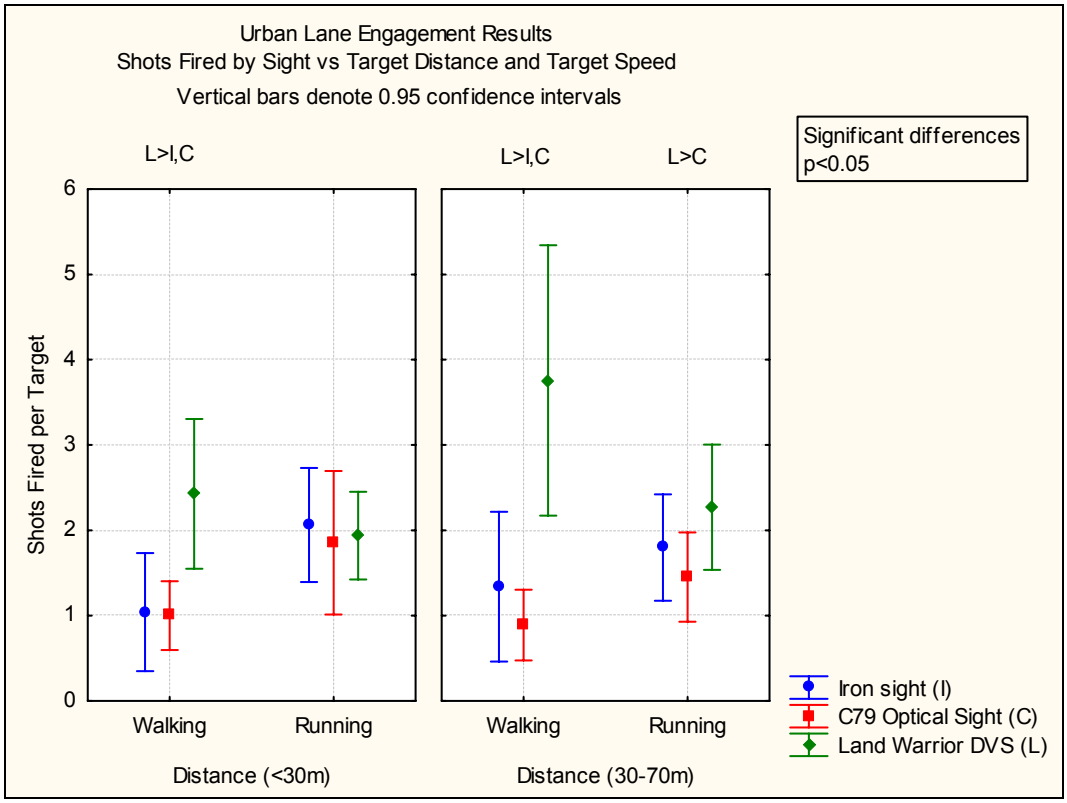

Figure 20: Mean Number of Shots Fired by Distance and Speed

At both near and far distances, soldiers using the Land Warrior sight required significantly ($p < .05$) more shots per hit than they did when using the C79 or Iron sight for targets at walking speed. For far running targets, when participants used the C79, they required significantly fewer shots per hit than when they used the Land Warrior.

5.2.3.3 Hit Accuracy and Shots Fired Sight Performance: Standing vs. Prone Posture

For the dynamic moving target test, no significant differences between postures were found in hit accuracy or the number of rounds fired per hit among any of the sights.

5.2.4 Shot Group Sizes

Consistency of aim was assessed by measuring the diameter of a five round grouping engagement trial. The average diameter of two shooting trials for each sight was used in the analysis of the grouping test.

The mean group diameter for the Iron, C79, Land Warrior and DCIEM sights were 423.5mm, 392.7mm, 431.28mm, and 330.9mm respectively in the standing firing position (see Figure 21). In the prone firing position, the mean group diameter for the Iron, C79, and Land Warrior sights were 205.3mm, 165.7mm, and 242.4mm respectively.

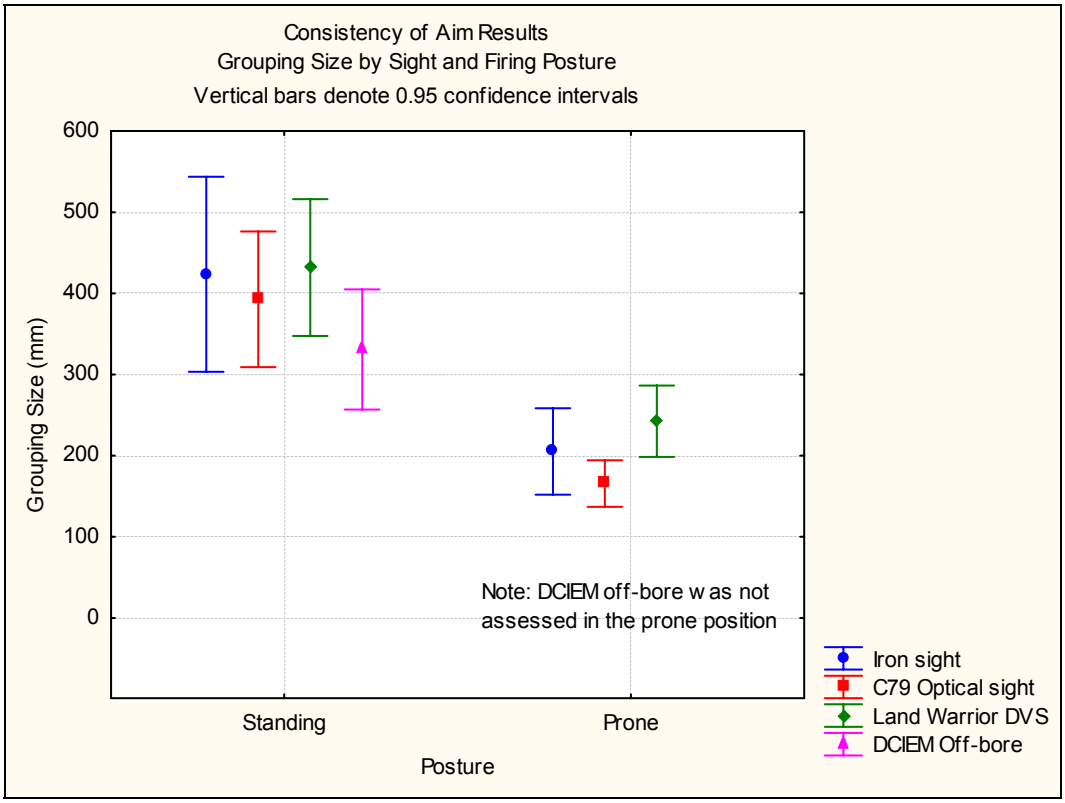

Figure 21: Shooting precision

While there was no overall significant difference between grouping sizes for the sights, there was a significant posture effect $F(1,11)=70.6$, $MS=805604$, $p=.00$). Soldiers using the prone firing position had grouping sizes 204 mm on average as compared to 416mm on average standing. (Please note the DCIEM sight grouping was only obtained in the standing position only.) The group sizes for the Iron, C79 and Land Warrior sights were significantly ($p < .05$) smaller in the prone position than in the standing position.

5.2.5 Aim Time

The time to acquire and hit a target was also measured for each sight in the standing position. On command, participants were required to rapidly turn around and engage a target and hit it as soon as possible. To be valid, participants were required to hit the target within three shots. While all 12 participants could hit the target within three shoots for the Iron, C79 and DCIEM sights, only six participants could do so with the Land Warrior system. As a result the need to hit the target within three shots was dropped so that all the land Warrior engagements could be examined.

Aiming times for the Iron, C79, Land Warrior and DCIEM sight were 4.5s, 4.5s, 7.2s and 5.3s respectively (see Figure 22).

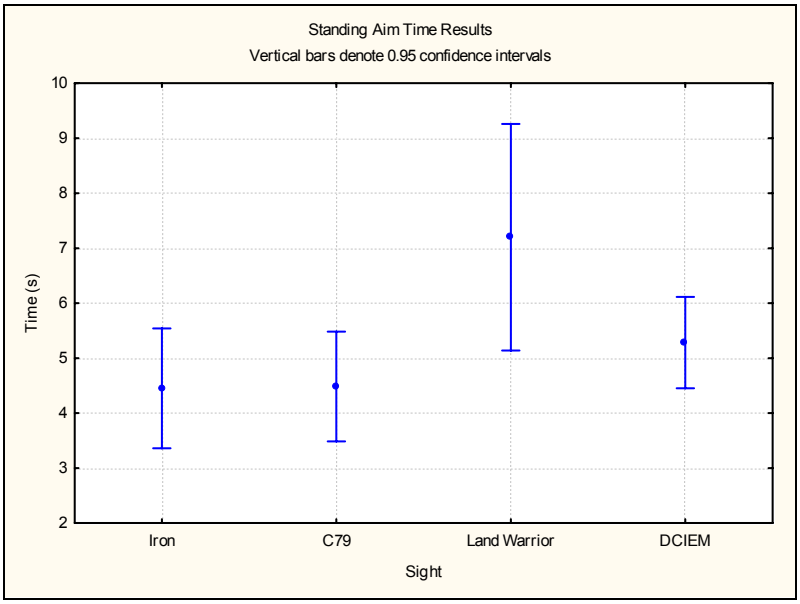

Figure 22: Mean aim time for the sighting systems

Significant differences were observed when all the Land Warrior aiming times were included F (3, 33)=6.23, MS=19.95, p= .001. Participants using the Land Warrior DVS took significantly longer to acquire and hit a static target. No significant differences were observed between the Iron, C79 and DCIEM sights for aim time.

Because six participants could not hit the target after three attempts with the Land Warrior sight, only six of the participants' data were included. The aim time data for the Land Warrior may therefore not be accurately representative of its performance, but the results do imply that participants had increased difficulty in quickly aiming with the unmagnified off-bore sight.

5.3 Qualitative Results

Soldiers completed a Task/Compatibility Questionnaire at the end of each sight serial, and a Criteria of Importance Questionnaire at the end of all their serials. All the participants also participated in an Exit Focus Group in which they voiced their opinions on the sights as a group.

5.3.1 Task and Compatibility Questionnaire

After each shooting serial, participants completed a Task/Compatibility Questionnaire about the sight system they had used. They rated the acceptability of various aspects of the sight using the standard 7 point rating scale.

5.3.1.1 Vision/Optics

Each sight was rated on the following visual/optics criteria: magnification; field of view; freedom from glare; alignment demands; freedom from fogging; and eye relief. The results are depicted in Figure 23.

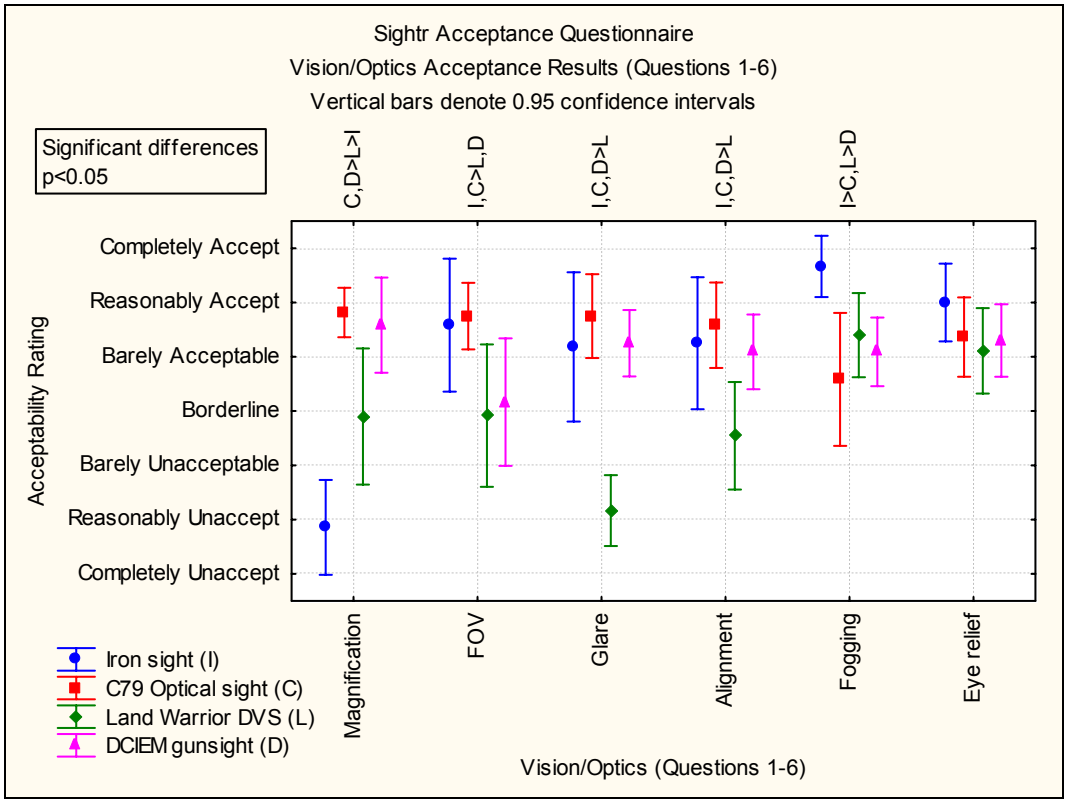

Figure 23: Sight acceptability questionnaire – vision/optics

Please note that although the graph describes results for all of the questions, a repeated measures ANOVA was conducted separately for each criteria for the four sights.

The C79 and the DCIEM off-bore sights both had 3.4x magnification, whereas, the Land Warrior and Iron sight did not. When rating magnification, the C79 and DCIEM sights were rated between "Barely Acceptable" and "Reasonable Acceptable", which was significantly higher (F (3, 33)=19.1, MS=40.3, p=.00) than the "Borderline" rating for the Land Warrior sight. All three sights were rated significantly higher than the "Reasonably Unacceptable" rating of the Iron sight.

With respect to field of view, participants rated the Iron and C79 sights between "Barely Acceptable" and "Reasonably Acceptable", which was a significantly higher(F(3,33)=3.56, MS=10.7, p=.02) rating than the "Borderline" rating for the Land Warrior and DCIEM off-bore sights.

For the freedom from glare criterion, participants rated the Iron, C79, and DCIEM sights between "Barely Acceptable" to "Reasonably Acceptable". This was significantly higher(F(3, 33)=17.88, MS=32, p=.00) than the "Reasonably Unacceptable" rating of the Land Warrior sight.

Regarding alignment demands, the Iron, C79 and DCIEM sights were rated between "Barely Acceptable" to "Reasonably Acceptable", which was significantly higher (F(3,33)=5.4, MS=9.8, p=.00) than the "Barely Unacceptable" to "Borderline" rating for the Land Warrior sight.

For the freedom from fogging criterion, participants gave the Iron sight a rating between "Reasonably Acceptable" to "Completely Acceptable", which was significantly higher(F(3,

33)=6.5, MS=9.5, p=.00)than the "Barely Acceptable" rating for the C79, Land Warrior, and DCIEM sights.

Participants rated eye relief between "Barely Acceptable" to "Reasonably Acceptable" for all of the sights. No significant difference was found for this criterion.

5.3.1.2 Functionality

Acceptability was rated by participants under the following criteria: ease of mounting; ease of zeroing; estimated maintenance of zero; sight bulk; sight weight; and estimated durability. The results are shown in Figure 24.

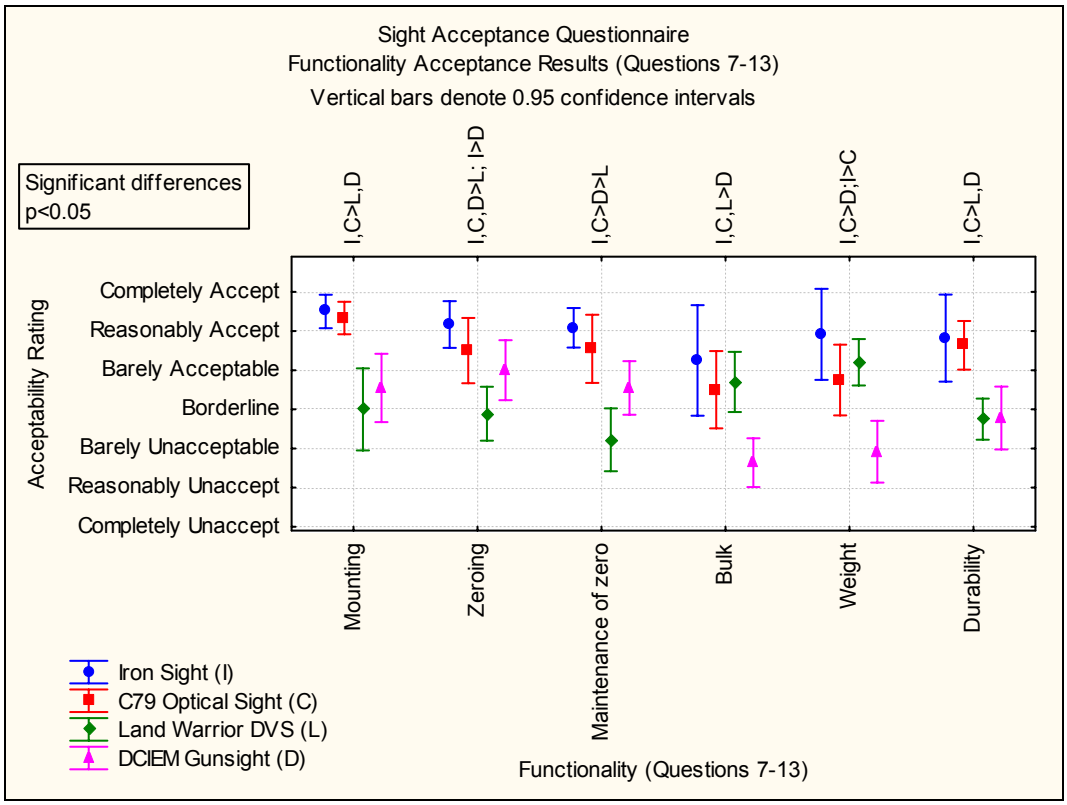

Figure 24: Sight acceptability questionnaire - functionality

Please note that although the graph describes results for all of the questions, a repeated measures ANOVA was conducted separately for each criteria for the four sights.

With respect to ease of mounting, participants rated the Iron and C79 between "Reasonably Acceptable" to "Completely Acceptable". This was significantly higher (F(3, 33)=14.4, MS=19.0, p=.00) than the "Borderline" to "Barely Acceptable" rating of the Land Warrior and DCIEM off-bore sights .

Participants rated the Iron, C79, and DCIEM sights between "Barely Acceptable" to "Reasonably Acceptable" for ease of zeroing, which was significantly higher (F(3, 33)=11.4, MS=11.0, p=.00) than the "Borderline" rating participants gave the Land Warrior sight. Also, the "Reasonably

Acceptable" rating of the Iron sight is significantly ($p < .05$) higher than the "Barely Acceptable" rating of the DCIEM sight.

For estimated maintenance of zero, participants rated the Iron and C79 between "Barely Acceptable" to "Reasonably Acceptable". This was significantly higher ($F(3, 33)=21.4$, $MS=18.98$, $p=.00$) than the "Borderline" to "Barely Acceptable" rating of the DCIEM sight. All three sights were rated significantly ($p < .05$) higher than the "Barely Unacceptable" rating participants gave the Land Warrior sight.

With respect to sight bulk, participants' ratings for the Iron, C79, and Land Warrior hovered around "Barely Acceptable". This was significantly higher ($F(3, 33)=8.1$, $MS=15.47$, $p=.00$) than the "Reasonably Unacceptable" to "Barely Unacceptable" rating of the DCIEM sight.

For the sight weight criterion, the Iron, C79, and Land Warrior were rated as "Barely Acceptable" to "Reasonably Acceptable", which was significantly higher ($F(3, 33)=12.2$, $MS=19.6$,$p=.00$) than the "Barely Unacceptable" rating of the DCIEM sight.

Participants rated the estimated durability for the Iron and C79 sights between "Barely Acceptable" to "Reasonably Acceptable". This was significantly higher ($F(3,33)=8.7$, $MS=15.5$, $p=.00$) than the "Borderline" rating participants gave the Land Warrior and DCIEM sights.

5.3.1.3 Task Demands

Participants rated task demands on the following criteria: target acquisition; speed of aiming; close-in target engagement; static target engagement; moving target engagement; prone firing; standing firing; and overall engagement. The results are shown in Figures 25 and 26.

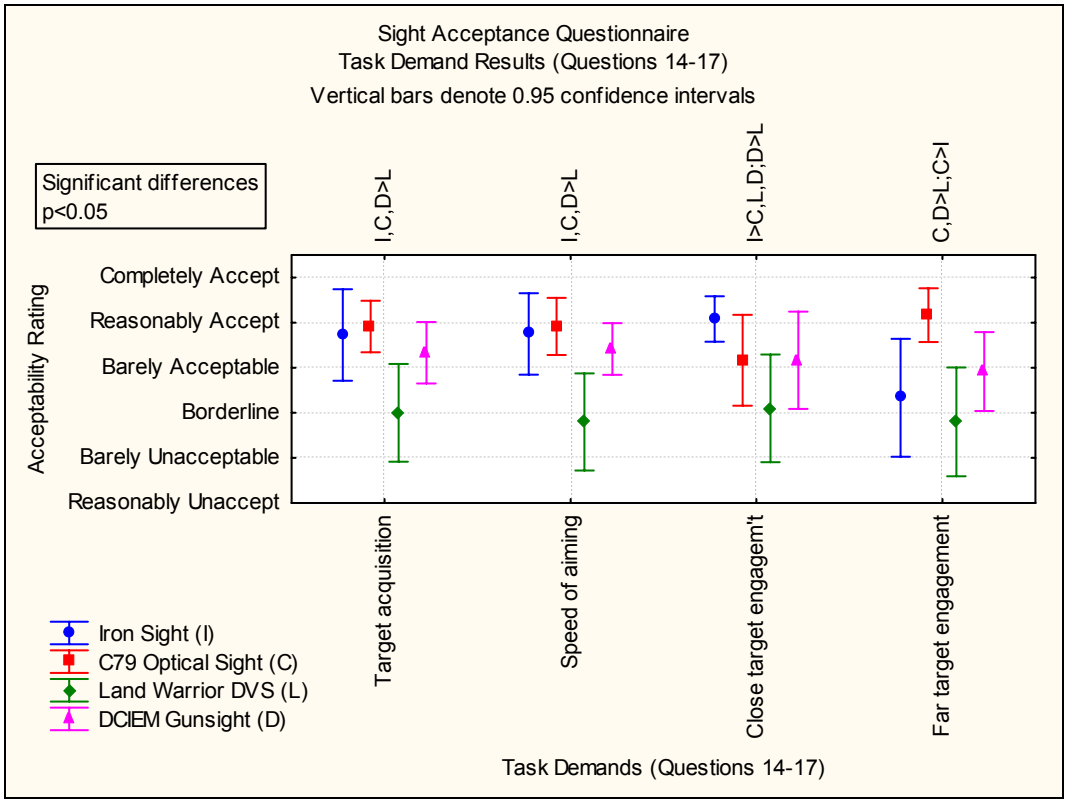

Figure 25: Sight acceptability questionnaire – task demands (1/2)

Please note that although the graph describes results for all of the questions, a repeated measures ANOVA was conducted separately for each criteria for the four sights.

For target acquisition, participants rated the Iron sight as "Reasonably Acceptable" to "Completely Acceptable" and the C79 and DCIEM sight as "Barely Acceptable" to "Reasonably Acceptable". These three sights were rated significantly higher ($F(3, 33)=6.0$, $MS=8.96$, $p=.00$) than the "Borderline" rating given to the Land Warrior sight.

When considering speed of aiming, participants' rated the Iron, C79, and DCIEM sights around "Reasonably Acceptable", which was a significantly higher ($F(3, 33)=8.0$, $MS=11.2$, $p=.00$) rating than the "Barely Unacceptable" to "Borderline" rating of the Land Warrior sight.

For the close-in target engagement criterion, the Iron sight was rated as "Reasonably Acceptable" to "Completely Acceptable" by participants. This was significantly higher ($F(3, 33)= 5.4$, $MS=7.89$, $p=.00$) than the "Barely Acceptable" rating of the C79 and DCIEM sight, and the "Borderline" rating of the Land Warrior. Further, the DCIEM sight was rated significantly higher than the Land Warrior sight.

With respect to far target engagement, the C79 was rated as "Reasonably Acceptable" to "Completely Acceptable" and the DCIEM sight as "Barely Acceptable" to "Reasonably Acceptable". Both of these were rated significantly higher ($F(3, 33)=4.3$, $MS=12.4$, $p=.01$) than the "Barely Unacceptable" to "Borderline" rating of the Land Warrior sight. Also, soldiers rated the C79 sight significantly higher than the "Borderline" to "Barely Acceptable" rating of the Iron sight.

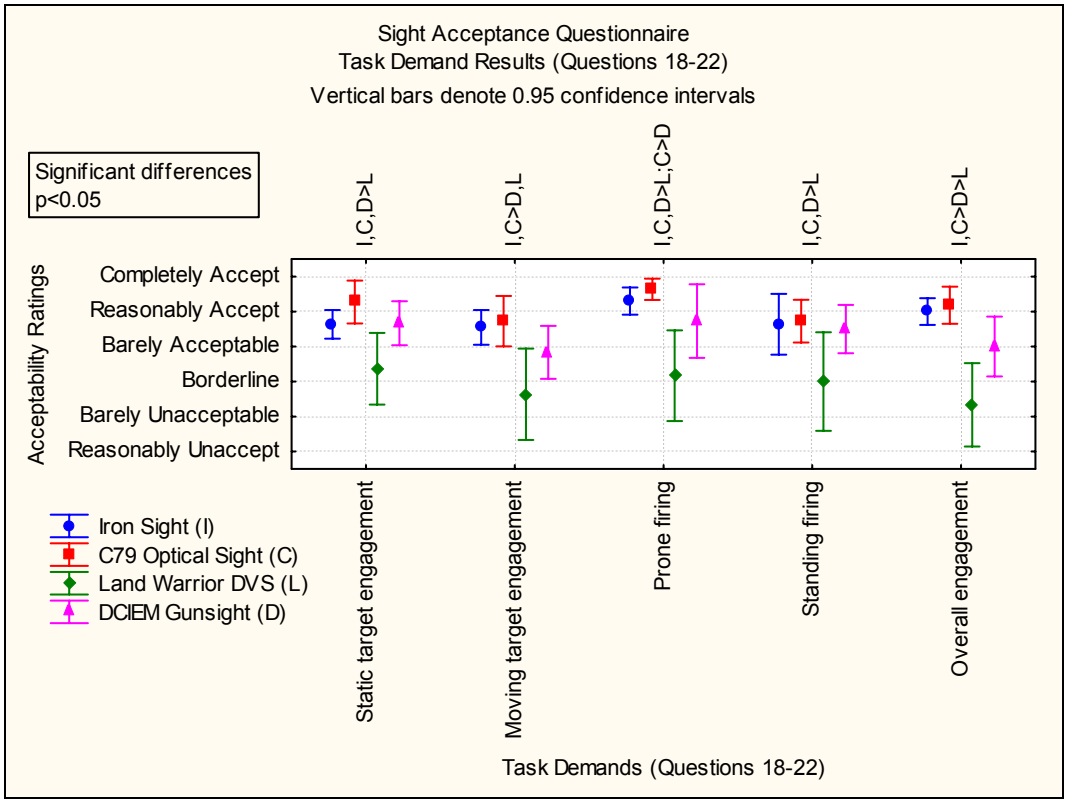

Figure 26: Sight acceptability questionnaire – task demands (2/2)

Please note that although the graph describes results for all of the questions, a repeated measures ANOVA was conducted separately for each criteria for the four sights.

For the static target engagement criterion, the C79 sight was rated by soldiers as "Reasonably Acceptable" to "Completely Acceptable", and the Iron and DCIEM sights were rated as "Barely Acceptable" to "Reasonably Acceptable". Participants rated all of these significantly higher (F(3, 33)=6.69, MS=7.7, p=.00) than the "Borderline" to "Barely Acceptable" rating of the Land Warrior.

With respect to moving target engagement, participants rated the Iron and C79 sights between "Barely Acceptable" to "Reasonably Acceptable", which was significantly higher than the "Barely Acceptable" rating of the DCIEM sight. These three sights were rated significantly higher (F(3, 33)=6.9, MS=10.8, p=.00) than the "Barely Unacceptable" to "Borderline" rating of the Land Warrior sight.

Considering prone firing, the C79 and Iron were rated by participants as "Reasonably Acceptable" to "Completely Acceptable" and the DCIEM sight was rated as "Barely Acceptable" to Reasonably Acceptable". Participants rated these three sights significantly higher (F(3, 33)=7.87, MS=14.35, p=.00) than the "Borderline" rating of the Land Warrior sight. Also, the C79 rating was a significantly higher rating than the DCIEM sight.

For the standing firing criterion, ratings for the Iron, C79, and DCIEM sight were between "Barely Acceptable" to "Reasonable Acceptable", which was rated significantly higher (F(3, 33) = 4.48, MS=7.99, p=.01) than the "Borderline" rating of the Land Warrior.

For overall day engagement performance (sight only), the Iron and C79 were rated as "Reasonably Acceptable". This was rated significantly higher than the "Barely Acceptable" rating of the DCIEM sight. However, the Iron, C79, and DCIEM were all rated significantly higher (F (3, 33)=12.97, MS=20.4, p=.00) than the "Barely Unacceptable" to "Borderline" rating of the Land Warrior.

5.3.1.4 Compatibility

Participants were asked to rate how compatible the sights were with the following: C7; helmet; equipment; maintenance; and cleaning. The results are depicted in Figure 27.

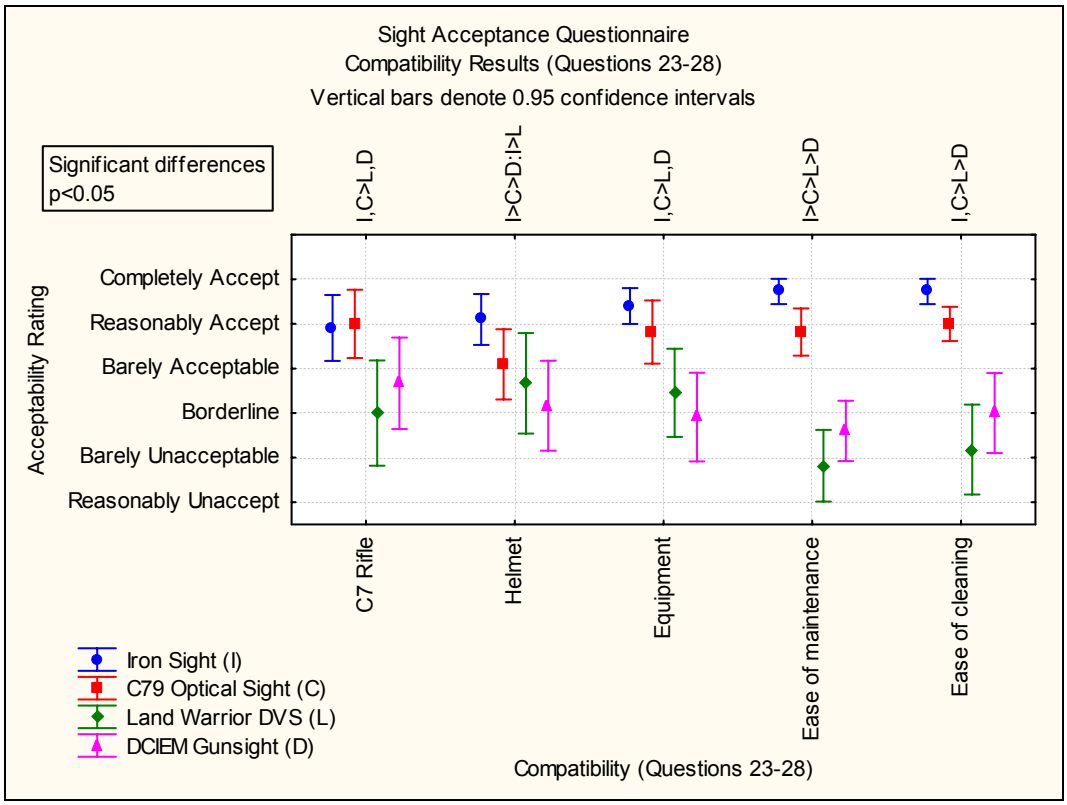

Figure 27: Sight acceptability questionnaire – compatibility

Please note that although the graph describes results for all of the questions, a repeated measures ANOVA was conducted separately for each criteria for the four sights.

When soldiers considered how compatible the sights each were with the C7, they rated the Iron and C79 sights as "Reasonably Acceptable". This was significantly higher (F(3, 33)=7.07, MS=11.4, p=.00) than the "Borderline" to "Barely Acceptable" rating that they gave the Land Warrior and DCIEM sight.

Regarding the compatibility with the helmet, participants rated the Iron sight as "Reasonably Acceptable", which was significantly higher (F(3, 33)=10.9, MS=13.4, p=.00) than the "Barely Acceptable" rating of the C79. Both the Iron and C79 sights were rated significantly higher by soldiers than the "Borderline" rating given to the DCIEM sight. The Iron sight was also rated significantly higher than the "Borderline" to "Barely Acceptable" rating of the Land Warrior system.

With respect to the compatibility with equipment, participants rated the Iron between "Reasonably Acceptable" and "Completely Acceptable", and the C79 as "Reasonably Acceptable". These ratings were significantly higher (F(3, 33)=13.6, MS=16.1, p=.00) than the "Borderline" to "Barely Acceptable" rating that soldiers gave the Land Warrior and DCIEM sights.

For the estimated ease of maintenance criterion, soldiers rated the Iron sight as "Completely Acceptable", which was significantly higher than the "Reasonably Acceptable" rating of the C79 sight. Participants rated both the Iron and C79 sights significantly higher (F(3, 33)=53.2, MS=40.4, p=.00) than the "Barely Unacceptable" to "Borderline" rating of the DCIEM sight. Further, the ratings for these three sights were rated significantly higher than the "Barely Unacceptable" rating of the Land Warrior sight.

For estimated ease of cleaning, the Iron and C79 sights were rated as "Reasonably Acceptable" to "Completely Acceptable". This was significantly higher than the "Borderline" rating of the DCIEM sight. The Iron, C79, and DCIEM sights were all rated significantly higher (F(3,33)=26.6, MS=33.1, p=.00) than the "Barely Unacceptable" rating given to the Land Warrior sight.

5.3.1.5 Overall Acceptability

Participants were asked to evaluate the overall acceptability of each sight with respect to static target engagement, moving target engagement, and everyday use. Results are shown in Figure 28.

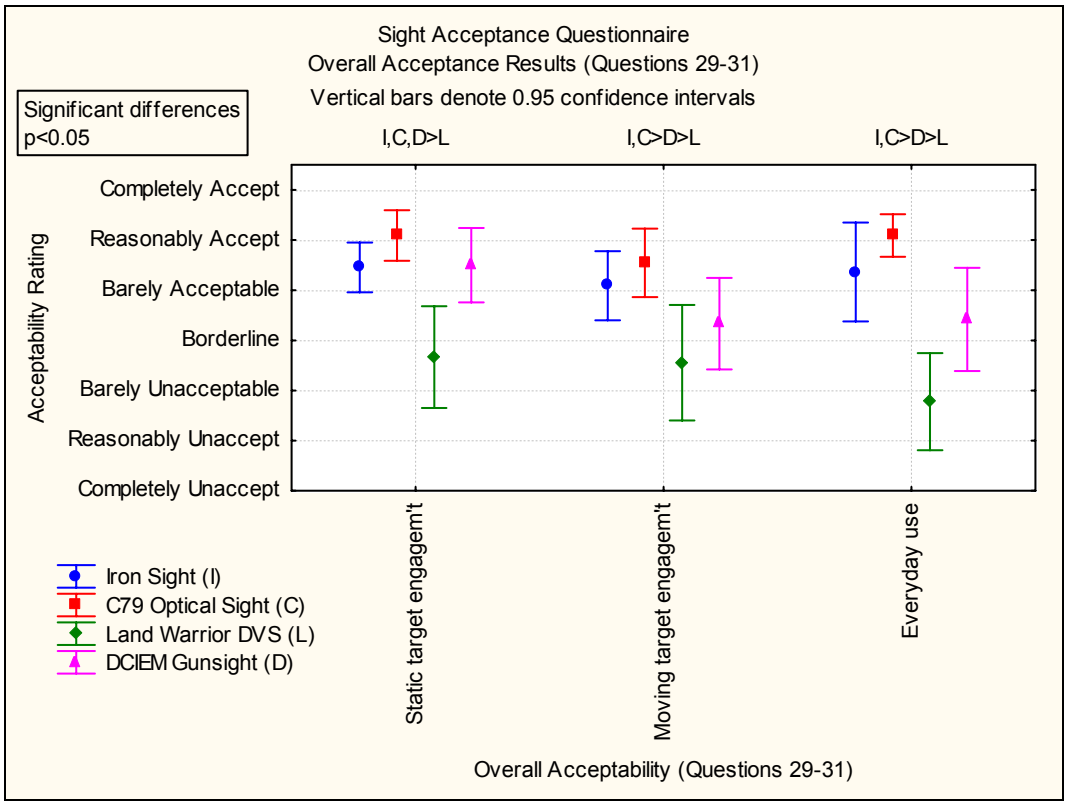

Figure 28: Sight acceptability questionnaire – overall acceptability

Please note that although the graph describes results for all of the questions, a repeated measures ANOVA was conducted separately for each criteria for the four sights.

When participants rated the overall acceptability of the sighting system for static target engagement, they rated the Iron sight as "Reasonably Acceptable" and the C79 and DCIEM sight between "Barely Acceptable" to "Reasonably Acceptable". These were all rated significantly higher ($F(3, 33)= 9.7$, $MS=40.4$, $p=.00$) than the "Barely Unacceptable" to "Borderline" rating of the Land Warrior sight.

For the overall acceptability of the sighting system for moving target engagement, the Iron and C79 sights were rated between "Barely Acceptable" to "Reasonably Acceptable", which was rated significantly higher than the "Borderline" to "Barely Acceptable" rating of the DCIEM sight. Again, these three sights were rated significantly higher ($F(3, 33)=4.8$, $MS=9.2$, $p=.00$) by participants than the rating for the Land Warrior sight, which fell between "Barely Unacceptable" to "Borderline".

Regarding the overall acceptability of the sighting system for every day infantry use, soldiers rated the C79 as "Reasonably Acceptable" and the Iron sight as "Barely Acceptable" to "Reasonably Acceptable". Both of these sights are rated significantly higher than the "Borderline" to "Barely Acceptable" rating of the DCIEM sight. All three sights were rated significantly higher ($F(3, 33) = 11.5$, $MS=24.5$, $p=.00$) than the "Reasonably Unacceptable" to "Barely Unacceptable" rating of the Land Warrior off-bore sight.

5.3.2 Criteria of Importance Questionnaire

The Criteria of Importance Questionnaire was administered at the end of testing. Soldiers rated their perceived importance of various design criteria for selecting or assessing a weapon sight. They rated each quality using a seven-point scale of importance. These ratings were then used to produce a criterion of importance rating. The complete mean ratings of importance and their standard deviations are displayed in Figure 29, sorted from highest to lowest importance.

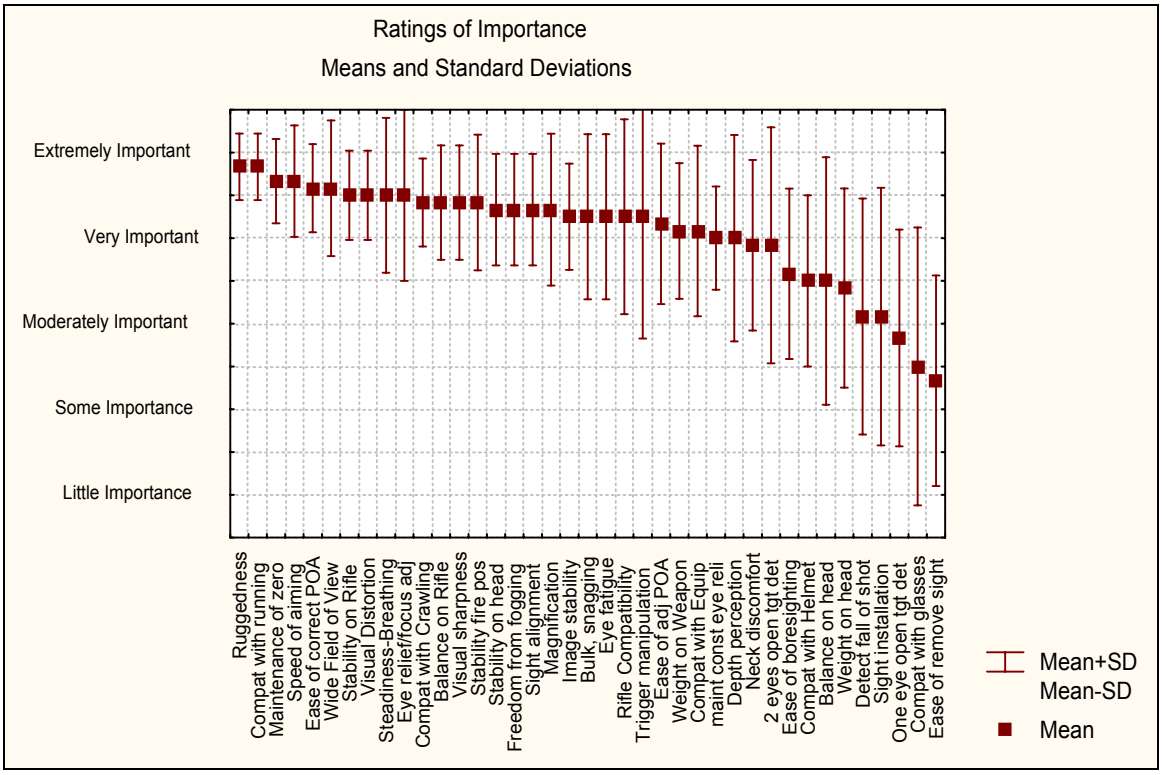

Figure 29: Criteria of Importance Questionnaire results

In the eyes of soldiers, at of the sight-related qualities were seen to have at least "some importance", and over half of the issues were considered between "very important" and "extremely important". The top two highest ratings of importance were ruggedness and compatibility with running, followed by maintenance of zero and speed of aiming. The lowest rated (that is, least important) features were ease of sight installation, one eye open target detection, compatibility with prescription glasses, and ease of removing sight.

5.3.3 Exit Focus Group

All participants attended a focus group at the end of the trial, and participated in providing comments on qualities of the various sights and desirable traits for yet-to-be-developed sights.

5.3.3.1 Vision/Optics

All of the participants agreed that some sort of magnification in a weapon sight is desirable. They believed that the ability to zoom would be ideal in a sight because the best compromise between magnification and field of view could be adjusted for a specific circumstance. Seventy-five percent (75%) of participants found that it was easier to shoot with magnification than without. Soldiers also indicated that they would like the option to zoom in further than 3.4x for some situations.

Reduced field of view was an issue for both magnified sights and HMD-based sights. Fifty-eight percent (58%) of participants experienced tunnel vision using the magnified C79 optical sight, and half experienced tunnel vision using the unmagnified HMD based Land Warrior.

Comparing the Ruggedized HMD of the Land Warrior with the Virtual Vision Sport HMD used with the DCIEM off-bore sight, participants commented that they preferred the smaller sized HMD on the DCIEM sight.

There was a concern about fogging obstructing vision on a goggle-style HMD mount such as the DCIEM's Virtual Vision Sport. Soldiers considered the Land Warrior HMD style to be superior because it only obstructed one eye. There was also a concern raised by the two participants who wore prescription glasses. They explained that the goggle mount of the Virtual Vision Sport HMD was not comfortably compatible with their glasses.

Sixty-six percent (66%) of soldiers mentioned that the Iron sight was the best sight (of the four tested) for quick, reaction shooting. Thirty-three percent (33%) said that it was the best for target shooting. Overall, participants considered the Iron sight the ideal field of view.

Comments indicated that some participants thought the ring size on the Iron sight (part of its reticle) was too small and the aiming post too large for accurately aiming at distant targets. The crosshair of the Land Warrior reticle was also criticized for being too thick, which consequently completely obscured small or distant targets. The dot of the DCIEM sight, although liked, was considered to be a poor choice of colour (white) because it could disappear when aiming at an area with a lightly coloured background. Soldiers suggested that a colour rarely found in nature would be superior for a sight reticle. They also suggested that the reticle be luminescent, and it should be adjustable.

5.3.3.2 Functionality

Comments indicated that soldiers thought the DCIEM sight's HMD had good eye relief. On the other hand, remarks indicated that almost all of participants had the Land Warrior's HMD move accidentally, making a good eye relief hard to maintain. According to soldiers' observations, the movement of its HMD stems from both looseness in the HMD mount, and movement of their helmet on which the HMD was mounted.

Participants rated the DCIEM weapon-mounted video sight to be too bulky. Over 80% of soldiers thought that the current standard issue C79 optical sight was also too bulky. The Land Warrior Daylight Video Sight was considered acceptable as far as weight and bulk. However, most of the soldiers thought that the Land Warrior webbing containing the computer system and batteries was too heavy as well as cumbersome. They mentioned that in a prone posture, the components attached to the front of the webbing got in the way.

Most of the soldiers shot from the hip while using the off-bore sights in a standing posture. Some of them commented that their breathing interfered with the stability of their aim-point with the magnified DCIEM video sight.

Seventy five percent (75%) of participants, however, thought that the Land Warrior Daylight Video Sight should be on the top of the weapon instead of the side. Comments indicated that it would be less difficult to look around corners with a top-mounted camera.

5.3.3.3 Task Demands

For target acquisition, over 80% of the soldiers thought that the Iron sight, with its unrestricted field of view, was the best of the four tested. The C79 was considered to be the next best, followed by the DCIEM off-bore. Most soldiers agreed that the Land Warrior was the worst of the four for

target acquisition. The DCIEM off-bore sight was considered the greater of the two off-bore sights because the magnification helped target recognition.

Eighty three percent (83%) of participants commented that the Iron sight was the quickest to aim, while the remaining 2 said it was the C79. Most soldiers thought that the Land Warrior was the slowest sight to aim. However, a few thought that the DCIEM off-bore sight, with its narrower field of view at full zoom, was worse.

For close target engagements, the Iron sight was considered the best. Three-quarters of the participants thought that the Land Warrior was the worst in this area, mostly because of the size and opacity of the reticle blocking the view of the targets, coupled with slow aiming.

For far target engagement, the soldiers preferred the magnified sights. Three-quarters of the participants favoured the DCIEM off-bore sight because they thought the reticle "dot" was better than the "post" on the C79. The Land Warrior and Iron sight were considered unsuitable for far target engagements. Soldiers explained that they were unmagnified and they both had a reticle that was too large.

For moving targets, 83% of the participants mentioned that the Iron sight was the best due to the unrestricted field of view. They recommended that a sight's reticle have horizontal "aiming marks" to assist in leading moving targets.

Finally, most of the soldiers thought that an off-bore system would be useful in a defensive situation. For patrolling situations, however, off-bore systems were considered too heavy. The participants also indicated that they thought an off-bore system could be useful in an urban combat situation. In such instances, magnification would not be as important.

6 Discussion

Across all static engagement ranges, the Land Warrior performed poorer than any other sighting system. The difference in the performance of the Land Warrior to the DCIEM gun sight may be attributed to any or all of the following parameters: the different camera lens systems, different camera sensor sizes, different display performances and finally different image processing systems. Although there were technological differences between the two off-bore systems, the results suggest that magnification may overcome camera and display resolution problems. All of the participants in the study stated that some sort of zoom was desirable.

The performance of the Land Warrior sight may have been affected by the automatic contrast adjustment of the Daylight Video Sight. When aiming at a target with a white background, the light exposure would automatically adjust, making the target fade so that it is difficult or impossible to see. Because the automatic light exposure adjustment occurred at the center point of the Daylight Video Sight, and this was causing problems in aiming during the pilot runs, the reticle was moved to the bottom right hand corner of the sight (improving the visibility dramatically). On the other hand, the DCIEM Helmet Mounted Gunsight had a manually adjustable "iris" which controlled the amount of light admitted to the video camera improving visibility.

Accuracy with the Land Warrior system was less than 5% at 150m in both the prone and standing position. These results suggest that the Land Warrior v 0.6 DVS system is not accurate enough to serve as a primary weapons sight (at ranges over 50m). The trial results also show that an optically magnified off-bore sight may be useful for urban detection and engagement. Any off-bore detection and engagement involves a penalty with increased detection and aiming times.

Both attributes of FOV and magnification were rated between "Very Important" and "Extremely Important" by the soldiers in their Criteria of Importance Questionnaires. The benefits of a wide FOV would be expected to show in a situation where a large range for searching for targets is presented. Magnification would be expected to aid in increasing shooting precision for all but the closest targets.

Overall, there was no significant difference in aiming time for the four sights. However, the conventional Iron and C79 sights had slightly shorter aiming times than the off-bore Land Warrior and DCIEM sights. These results are similar to the off-bore study performed by Van de Water, Kooi, & Benoist (1998). Because half of the participants did not even hit the target under time pressure while using the Land Warrior sight, this suggests that the Land Warrior did not perform as well as the other three sights for speed of aiming. Participants rated the speed of aiming significantly more acceptable for the C79, Iron, and DCIEM sight than for the Land Warrior sight.

Speed of aiming was affected by a number of factors. The image in the HMD from the camera becomes blurry as the camera is moved (as is done during motions made for aiming). This slight blurring, or smearing of the image, may be disorienting or make it more difficult to make the fine adjustments needed for aiming. Using a video sight and an active matrix LCD HMD, motion blur has been shown to cause a deterioration of image sharpness by a factor of 15 (Van de Water et al. 1998). As display and digital video technology improves so that high quality and fast frame-rate video sights become available, any differences in aiming time between on and off-bore sights may disappear, provided this is the cause for the delay. The additional weight (or off-center weight in the case of the Land Warrior) of the camera on the weapons for the off-bore sights may have

increased the aiming times. Extra weight and off-center weight have been shown to increase aim time and decrease accuracy (Yuan & Lee, 1997).

For gallery range engagements, participants considered the C79, Iron, and DCIEM sights more acceptable than the Land Warrior sight. The sights with the 3.4x magnification were significantly more acceptable than the sights with no magnification on the far target engagement criterion. For the close target engagement criterion, the conventional Iron sight was significantly more acceptable than the three other sights.

Considering moving target scenarios, the Land Warrior performed just as well as the on-bore sights for near targets at the running speed. For near targets (<50m) at the walking speed, the C79 performed better than the Land Warrior, but the Iron sight did not. At far distances (>50m), the Land Warrior performed worse than any of the on-bore sights at walking and running speed. Rating the acceptability of sights for moving targets, the conventional sights were considered more acceptable than the off-bore sights. The DCIEM sight was considered more acceptable than the Land Warrior sight for moving target engagement. The Iron sight may have performed well on the moving target scenarios relative to the magnified C79 because there were no targets greater than 100m. Thus, the search area was wide enough (larger than field of view of off-bore sights and C79) to allow for benefits to arise from the unrestricted FOV of the Iron sight.

7 Recommendations

The results of this experiment imply that magnification has a significant effect on sight performance, regardless of whether the sight is on-bore or off-bore. Although a non magnified, wide field of view sight is good for target detection, accurate aiming requires optical magnification. This combination of attributes could be achieved with a camera lens system that allows stepped or continuous zoom. Although the DCIEM camera system had a bulky motorized zoom system, the need for continuous zoom or even motorized zoom is debatable. Coupling a camera system with a manual two-stage lens system may be the best compromise. The soldier would search for targets with the unmagnified system, and when he detects a possible target, he would flip a lever such that a magnified lens is added to the optical pathway. The efficacy of such a system could be examined by pairing a unity powered camera and a magnified camera system with a switcher assembly, allowing the soldier to easily flip between two magnifications. The system should allow for the examination of various fixed magnification cameras coupled to an unmagnified camera.

It is also likely that a wider field of view would improve target search and detection. The lane used in the gallery range scenarios was very narrow, making the task merely target engagement without having to search and detect the target first. Future research should examine off-bore sights in a target search and detection task. This research would examine the implications of the smaller field of view of the off-bore sights compared to the conventional sights. The percentage of targets hit in the static target/gallery range scenarios was poor across all eight lateral locations of the targets for the off-bore Land Warrior sight. For the conventional Iron and C79 sights a significantly higher number of targets in the center or right of the lane were hit in comparison to the left side of the lane.

Recommendations from the focus group indicate that soldiers would like an HMD designed like the Land Warrior HMD to cover one eye, but smaller. The reticle should be a dot with some non-obstructive horizontal lead assist marks. The reticle should also be a colour not found often in nature (red was suggested) and adjustable in brightness (for low or high light conditions).

Target engagement of static targets ranging from 50m to 150m as well as moving targets ranging from 30m to 80m were examined. In future research of off-bore sights, the use of more static range bands (i.e. 50m, 75m, 100m,125m, 150m, 175m…) and more moving target range bands (50m , 75m, 100m, 125m…) should be examined in order to see a more detailed picture of exactly when unmagnified and magnified off-bore sight performance drops off.

Off-bore sights should also be examined at a real gallery range with live fire, and in an urban environment with more realistic time pressures and context.

In conclusion, off-bore sights should be able to perform as well as conventional sights if they have proper magnification, a high-quality fast-refresh rate display, low weight on the weapon, a small yet visible reticle, and an effective system for managing light exposure. These technical improvements should help with the speed of aiming for off-bore sights, which is a feature considered critically important by soldiers. Other critically important considerations in the design of the future off-bore sight would be ruggedness and maintenance of zero.

The Land Warrior system that was available at the time of testing was version 0.6. Future versions of the Land Warrior system will include improvements such as those recommended in this study, such as magnification, a new reticle, and a better system for light exposure adjustment. These

changes may improve the shooting performance of the Land Warrior system and lead to increased soldier acceptance. Thus, further tests on the future Land Warrior system would indicate whether these recommended changes bring the performance of the Land Warrior to the level of the DCIEM off-bore and Optical C79 sight.

The camera systems used in this trial were state of the art during their development periods. They are now outdated. Instead of 640 X 480 pixel VGA resolution camera systems, there are now 1300 x 1030 pixels Mega pixel cameras in existence. The four times increase in pixel density will greatly enhance camera resolution. It is possible that Mega pixel cameras will now successfully permit electronic zone of images. The benefits of Mega pixel cameras should be investigated with regards to resolution, frame rate, electronic versus optical zoom, etc.

Although the Land Warrior Kaiser helmet mounted display is a very capable system, the display is limited to VGA resolution (640 x 480 pixels). A retinal display system from Microvision Inc. is currently being tested that increases HMD resolution to the SVGA region (800 x 600 pixels). Improving display resolution should by definition improve soldier performance. The benefits of higher resolution HMDs should be examined.

8 References

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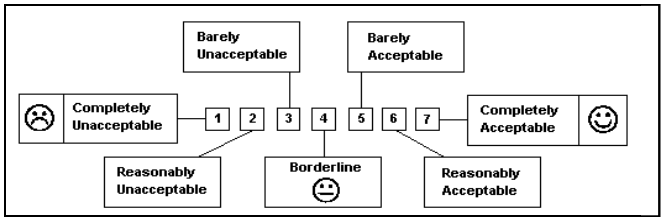
ANNEX A:
Task/Compatibility Questionnaire



PERSONNEL INFORMATION	**Clearly print your subject number, and indicate your sight. Please note some o f the questions may not apply to all sights.**	
Subject Number: ☐☐☐ **Date:** _____	**Sight Type:** **Iron sight** ○ **C79** ○ **Off-bore** ○	
Please rate the following criteria	**Acceptance Rating** ☹ 1 2 3 😐 4 5 6 ☺ 7	**Comments**
VISION/OPTICS		
Magnification	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Field of view	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Reticle pattern	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Reticle contrast ratio	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Reticle contrast adjustability	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Automatic reticle brightness adjustment	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Freedom from glare	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Alignment demands	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Freedom from fogging	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Eye Relief	☐ ☐ ☐ ☐ ☐ ☐ ☐	

Please rate the following criteria	Acceptance Rating ☹ 1 2 3 ☻ 4 5 6 ☺ 7	Comments
FUNCTIONALITY		
Ease of mounting	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of zeroing	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Estimated maintenance of zero	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Ease of battery changing	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Ease of checking battery life	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Sight bulk	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Sight weight	☐ ☐ ☐ ☐ ☐ ☐ ☐	
HMD bulk	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
HMD weight	☐ ☐ ☐ ☐ ☐ ☐ ☐	(If appropriate)
Estimated durability	☐ ☐ ☐ ☐ ☐ ☐ ☐	
TASK DEMANDS		
Target acquisition	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Speed of aiming	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Close-in target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Far target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	

Please rate the following criteria	Acceptance Rating ☹ 1 2 3 4 5 6 7 ☺	Comments
TASK DEMANDS (CONTINUED)		
Static target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Moving target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Prone firing	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Standing firing	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Overall day engagement performance (sight only)	☐ ☐ ☐ ☐ ☐ ☐ ☐	
COMPATIBILITY		
Compatibility with C7	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Compatibility with helmet	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Compatibility with equipment	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Estimated ease of maintenance	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Estimated ease of cleaning	☐ ☐ ☐ ☐ ☐ ☐ ☐	

OVERALL ACCEPTANCE		
Overall acceptability of the sighting system for static target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Overall acceptability of the sighting system for moving target engagement	☐ ☐ ☐ ☐ ☐ ☐ ☐	
Overall acceptability of the sighting system for every day infantry use.	☐ ☐ ☐ ☐ ☐ ☐ ☐	
COMMENTS		

ANNEX B:
Criteria of Importance Questionnaire

PERSONNEL INFORMATION	Clearly print your subject number and rate the relative importance of the following factors for Sight selection.
Subject Number	☐☐☐

Rate the importance of the following criteria	*Importance Rating Scale*						
	Of No Importance	Of Slight Importance	Of Little Importance	Of Some Importance	Moderately Important	Very Important	Extremely Important
Functionality							
Ease of sight installation	☐	☐	☐	☐	☐	☐	☐
Ease of sight collimation (bore sighting)	☐	☐	☐	☐	☐	☐	☐
Ease of eye relief/ focus adjustment	☐	☐	☐	☐	☐	☐	☐
Bulk, snagging	☐	☐	☐	☐	☐	☐	☐
Ruggedness	☐	☐	☐	☐	☐	☐	☐
Maintenance of sight zero	☐	☐	☐	☐	☐	☐	☐
Ability to remove sight for storage	☐	☐	☐	☐	☐	☐	☐
Physical Demands							
Weight on the head	☐	☐	☐	☐	☐	☐	☐
Weight on the weapon	☐	☐	☐	☐	☐	☐	☐
Eye fatigue	☐	☐	☐	☐	☐	☐	☐
Neck discomfort	☐	☐	☐	☐	☐	☐	☐
Balance on the head	☐	☐	☐	☐	☐	☐	☐
Stability on the head	☐	☐	☐	☐	☐	☐	☐
Balance on the rifle	☐	☐	☐	☐	☐	☐	☐
Stability on the rifle	☐	☐	☐	☐	☐	☐	☐
Rifle compatibility	☐	☐	☐	☐	☐	☐	☐
Compatibility with Rx glasses	☐	☐	☐	☐	☐	☐	☐

Rate the importance of the following criteria	*Importance Rating Scale*						
	Of No Importance	Of Slight Importance	Of Little Importance	Of Some Importance	Moderately Important	Very Important	Extremely Important
Compatibility (continued)							
Compatibility with helmet	☐	☐	☐	☐	☐	☐	☐
Compatibility with equipment	☐	☐	☐	☐	☐	☐	☐
Compatibility with tactical movement -crawling	☐	☐	☐	☐	☐	☐	☐
Compatibility with tactical movement -running	☐	☐	☐	☐	☐	☐	☐
Vision							
Visual sharpness - resolution	☐	☐	☐	☐	☐	☐	☐
Freedom from visual distortion	☐	☐	☐	☐	☐	☐	☐
Wide field of view	☐	☐	☐	☐	☐	☐	☐
Freedom from fogging	☐	☐	☐	☐	☐	☐	☐
Image stability	☐	☐	☐	☐	☐	☐	☐
Depth perception	☐	☐	☐	☐	☐	☐	☐
Magnification	☐	☐	☐	☐	☐	☐	☐
Target Engagement Tasks							
Two eyes open target detection	☐	☐	☐	☐	☐	☐	☐
One eye open target detection	☐	☐	☐	☐	☐	☐	☐
Ease of obtaining the correct sight alignment	☐	☐	☐	☐	☐	☐	☐
Ease of obtaining the correct point of aim	☐	☐	☐	☐	☐	☐	☐
Ease of maintaining constant eye relief between shots	☐	☐	☐	☐	☐	☐	☐

Rate the importance of the following criteria	*Importance Rating Scale* Of No Importance	Of Slight Importance	Of Little Importance	Of Some Importance	Moderately Important	Very Important	Extremely Important
Target Engagement Tasks (continued)							
Speed of aiming	☐	☐	☐	☐	☐	☐	☐
Steadiness (adopting stable fire positions)	☐	☐	☐	☐	☐	☐	☐
Steadiness (trigger manipulation)	☐	☐	☐	☐	☐	☐	☐
Steadiness (effects of breathing)	☐	☐	☐	☐	☐	☐	☐
Ability to detect fall of shot	☐	☐	☐	☐	☐	☐	☐
Ease of adjusting point of aim	☐	☐	☐	☐	☐	☐	☐
Comments							

	Sight Preferences							
	Strongly Pref.	Mod. Pref.	Slightly Pref.	Neutral	Slightly Pref.	Mod. Pref.	Strongly Pref.	
Magnification (narrow field of view)	○	○	○	○	○	○	○	No magnification (wide field of view)
Two eyes open target acquisition and sight alignment (rapid acquisition and rough alignment)	○	○	○	○	○	○	○	One eye open target acquisition and sight alignment (deliberate acquisition and rough alignment)
Single aiming mark	○	○	○	○	○	○	○	Mutliple aiming marks (front post, rear aperature)
Lethality (retain existing detection and engagement abilities but remain exposed)	○	○	○	○	○	○	○	Protection (ability to remain under cover but detection and engagement performance is compromised)
Digital video sight as a detection system only	○	○	○	○	○	○	○	Digital video sight for detection and engagement
Iron sight	○	○	○	○	○	○	○	C79 Optical sight
Iron sight	○	○	○	○	○	○	○	Digital video sight
C79 Optical sight	○	○	○	○	○	○	○	Digital video sight
Ability to adopt conventional fire positions	○	○	○	○	○	○	○	Ability to adopt non-conventional fire positions
Weapon mounted sights	○	○	○	○	○	○	○	Head or helmet mounted sight displays
Robust sight (maintains zero, no performance augmentation)	○	○	○	○	○	○	○	Sights providing performance augmentation (less robust)
Dedicated sight	○	○	○	○	○	○	○	Modular system
	○	○	○	○	○	○	○	
	○	○	○	○	○	○	○	
	○	○	○	○	○	○	○	
	○	○	○	○	○	○	○	

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(U) A 6−day laboratory study was undertaken at Defence Research and Development Canada (DRDC) Toronto, Canada over the period September 21 to September 28, 2001. Twelve−reserve force infantry soldiers assessed the engagement performance of two different off−bore sights, the unmagnified U.S. Land Warrior system and the magnified DCIEM Helmet Mounted Gunsight, against two conventional sights (magnified optical C79 and unmagnified Iron), in a small arms simulator. The shooting tests consisted of a test of time to aim, and tests of shooting precision in the prone and standing position against static and moving targets.

The results of time to aim indicated difficulty in quickly aiming with the unmagnified off−bore sight (Land Warrior), and minimal difference in aiming time between the magnified off−bore sight and the conventional sights. Shooting precision was found to be equal between off−bore and on−bore sights, with one exception. Shooting precision was better with the C7 optical sight in comparison to the Land Warrior when participants were in the prone posture. In the gallery range, the magnified off−bore sight performed as well as the magnified optical C79 sight; whereas, the unmagnified off−bore sight performed the worst. For moving targets, the magnified off−bore sight was not tested, and the conventional sights generally outperformed the unmagnified off−bore sight, but o.nly marginally at close (Based on observations and results from this study, recommendations for future research and investigations are discussed.

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; off−bore sight; Land Warrior system; DCIEM Helmet Mounted Gunsight; off−bore shooting; engagement accuracy; disconnected rifle sight; off−axis aiming