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INVESTIGATION OF ALTERNATIVE TARGET DESIGNATION METHODS

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Abstract

An eight-day field trial was undertaken at Fort Benning, Georgia to investigate the impact of new technologies on the target designation task. This experiment compared the objective and subjective performance of soldiers using three conditions: a compass and paper map baseline; a paper map with a laser rangefinder; and a geo-referenced digital map in conjunction with a laser rangefinder and target designation software.

Findings from this experiment demonstrated that the laser rangefinder, used either with the paper map or integrated with the GPS-based digital map, was more effective and efficient than the current in-service means (i.e. paper map, compass, and M-22 binoculars). The objective results showed that participants were more than twice as accurate using the laser rangefinder in designating targets as compared to the baseline condition. The digital map/laser rangefinder system was also much faster than the other two conditions at designating targets.

Participants recognized that their ability to determine their own location on the map directly affected the accuracy with which targets could be designated on the map. Participants reported that the digital map/laser rangefinder system was a significant improvement over paper map methods for the accuracy and time required to plot target entities on the map. As well, targets plotted on the digital map could be easily transmitted as a report on a digital battlefield network, thereby reducing the risk of errors due to radio transfer and transcription. Overall, the GPS-based digital map integrated with the laser rangefinder greatly improved and enhanced the capabilities of infantry soldiers to perform target designation tasks.

Résumé

Un essai d'une durée de huit jours a été effectué à Fort Benning (Géorgie) afin d'examiner les incidences de nouvelles technologies sur la désignation d'objectifs. Cette expérience visait à comparer la performance objective et subjective de soldats utilisant trois dispositifs : un dispositif de référence comportant une boussole et une carte papier; une carte papier avec un télémètre laser; une carte numérique géoréférencée combinée à un télémètre laser et à un logiciel de désignation d'objectifs.

Les résultats de cette expérience ont démontré que le télémètre laser, utilisé avec la carte papier ou intégré à la carte numérique à positionnement GPS, était plus efficace et plus efficient que les moyens actuellement utilisés (carte papier, boussole et jumelles M-22). Les résultats objectifs ont indiqué que, pour désigner des objectifs, les participants obtenaient une exactitude deux fois plus grande à l'aide du télémètre laser comparativement au dispositif de référence. En outre, le système à carte numérique/télémètre laser était beaucoup plus rapide que les deux autres dispositifs pour la désignation d'objectifs.

Les participants ont constaté que leur capacité de déterminer leur propre position sur la carte influençait directement l'exactitude avec laquelle les objectifs pouvaient y être désignés. Les participants ont indiqué que le système à carte numérique/télémètre laser représentait une amélioration substantielle par rapport aux méthodes utilisant des cartes papier, en ce qui a trait à l'exactitude et au temps requis pour reporter des objectifs sur la carte. En outre, les objectifs reportés sur la carte numérique pouvaient aisément être transmis sous forme de rapport par un réseau numérique pour le champ de bataille, réduisant ainsi les risques d'erreur par suite du transfert par radio et de la transcription. En général, la carte numérique à positionnement GPS intégrée au télémètre laser a permis d'améliorer et de rehausser considérablement les capacités des soldats d'infanterie dans l'exécution de leurs tâches de désignation d'objectifs.

Executive Summary

Terrain navigation and target designation are two critical operational functions required of the dismounted infantry soldier. The speed, precision, accuracy, and ease of performing these tasks with the current in-service methods are a concern and previous navigation studies have identified several areas for improvement. One concern involves the potential for large offset errors in target designation due to inaccuracies in determining one's own location on the map. When "own location" error was combined with any errors associated with the target designation task using conventional in-service means, these concerns would be compounded. To investigate the impact of new technologies on the target designation task, this experiment compared the objective and subjective performance of soldiers using three conditions: a compass and paper map baseline; a paper map with a laser rangefinder; and a geo-referenced digital map in conjunction with a laser rangefinder and target designation software.

An eight-day field trial was undertaken at Fort Benning, Georgia over the period of 4-13 May 2004. Sixteen regular force infantry soldiers from the 3rd Battalion Princess Patricia Canadian Light Infantry (3PPCLI), based in CFB Edmonton, participated in these investigations. From three fixed locations, participants were required to designate the position of selected target features within specified zones (near, middle, far) using three target designation methods and report those locations.

Findings from this experiment demonstrated that the use of the laser rangefinder, when used alone with the paper map or when integrated with the GPS-based digital map, was more effective and efficient than the current in-service means (paper map, compass, and M-22 binoculars). The objective results showed that participants were more than twice as accurate using the laser rangefinder in designating targets as compared to the baseline condition. The digital map/laser rangefinder system was also much faster than the other two conditions at designating targets.

Subjective findings from questionnaire data and focus group discussions also confirmed that participant's perceived the accuracy of the laser rangefinder, and the associated reduction in time to determine an accurate bearing and distance to target entities, to be a significant improvement over current methods. While the laser rangefinder proved very effective in minimizing bearing and distance estimation error, this technology alone did not address concerns with errors in determining "own location" nor did it reduce plotting and reporting time. Participants recognized that their ability to determine their own location on the map directly affected the accuracy with which targets could be designated on the map. Participants reported that the digital map/laser rangefinder system was a significant improvement over paper map methods for the accuracy and time required to plot target entities on the map. As well, targets plotted on the digital map could be easily transmitted as a report on a digital battlefield network, thereby reducing the risk of errors due to radio transfer and transcription.

However, participants reported concerns with the compatibility, durability, and tactical suitability of the experimental system used to test the digital map/laser rangefinder combination. Participants indicated that the exposed cabling/wiring, and the bulk and weight of the system, introduced some incompatibilities with existing clothing, weapons, and equipment. They suggested that any future system needed to be much more rugged, lighter and smaller, with no snagging hazards before it would be considered tactically feasible.

Even with these limitations, participants unanimously agreed that the digital map/laser rangefinder system would be an extremely valuable addition to soldiering capabilities, if issues associated with size, weight, and cabling could be adequately addressed. The GPS-based digital map integrated with the laser rangefinder greatly improved and enhanced the capabilities of infantry soldiers to perform target designation tasks.

Sommaire

La navigation sur le terrain et la désignation d'objectifs sont deux fonctions opérationnelles essentielles exigées du soldat d'infanterie débarquée. La vitesse, la précision, l'exactitude et la facilité d'exécution de ces tâches à l'aide des méthodes actuelles font partie de nos préoccupations et des études antérieures sur la navigation ont permis d'identifier plusieurs aspects à améliorer. L'une de ces préoccupations a trait au fait que l'inexactitude de la position du participant lui-même sur la carte peut entraîner d'importants décalages lors de la désignation d'objectifs. Lorsque l'erreur d'un participant'sur sa « propre position » est combinée avec toute autre erreur associée à la désignation d'objectifs à l'aide des moyens classiques actuellement utilisés, les sujets de préoccupation se multiplient. Afin d'examiner les incidences de nouvelles technologies sur la désignation d'objectifs, cette expérience visait à comparer la performance objective et subjective de soldats utilisant trois dispositifs : un dispositif de référence comportant une boussole et une carte papier; une carte papier avec un télémètre laser; une carte numérique géoréférencée combinée à un télémètre laser et à un logiciel de désignation d'objectifs.

Un essai d'une durée de huit jours a été effectué à Fort Benning (Géorgie) au cours de la période du 4 au 13 mai 2004. Seize soldats de l'infanterie de la force régulière du 3e Bataillon, Princess Patricia's Canadian Light Infantry (3PPCLI), de la Base des Forces canadiennes Edmonton (BFC Edmonton), ont participé a cette étude. À partir de trois emplacements déterminés, les participants devaient désigner la position d'objectifs choisis dans des zones spécifiques (proche, médiane, éloignée), à l'aide de trois méthodes de désignation d'objectifs, puis signaler ces emplacements.

Les résultats de cette expérience ont démontré que le télémètre laser, utilisé seul avec la carte papier ou intégré à la carte numérique à positionnement GPS, était plus efficace et plus efficient que les moyens actuellement utilisés (carte papier, boussole et jumelles M-22). Les résultats objectifs ont indiqué que, pour désigner des objectifs, les participants obtenaient une exactitude deux fois plus grande à l'aide du télémètre laser comparativement au dispositif de référence. En outre, le système à carte numérique/télémètre laser était beaucoup plus rapide que les deux autres dispositifs pour désigner des objectifs.

Les résultats subjectifs, issus des données recueillies au moyen de questionnaires et de groupes de discussion, ont également confirmé que, selon la perception des participants, l'exactitude du télémètre laser, ainsi que la réduction du temps nécessaire pour faire un relèvement exact des objectifs et de leur distance, constituait une nette amélioration comparativement aux méthodes actuelles. Bien que le télémètre laser se soit avéré très efficace pour réduire les erreurs d'estimation des relèvements et des distances, cette technologie utilisée seule ne pouvait régler les problèmes d'erreurs lorsqu'un participant déterminait sa « propre position », ni réduire le temps requis pour reporter sur une carte et signaler les positions. Les participants ont indiqué que le système à carte numérique/télémètre laser représentait une amélioration substantielle par rapport aux méthodes utilisant des cartes papier, en ce qui a trait à l'exactitude et au temps requis pour reporter des objectifs sur la carte. En outre, les objectifs reportés sur la carte numérique pouvaient aisément être transmis sous forme de rapport par un réseau numérique pour le champ de bataille, réduisant ainsi les risques d'erreur en raison du transfert par radio et de la transcription.

Toutefois, les participants ont fait part de leurs préoccupations au sujet de la compatibilité, la durabilité et la pertinence stratégique du dispositif expérimental utilisé pour l'essai de la combinaison carte numérique/télémètre laser. Ils ont indiqué que le câblage à découvert, ainsi que la masse et le poids du dispositif, présentaient certaines incompatibilités avec les vêtements, les armes et l'équipement existants. Selon eux, pour être considéré utilisable d'un point de vue stratégique, tout nouveau système devrait être beaucoup plus robuste, plus léger et plus petit, sans risquer de s'accrocher.

Malgré ces restrictions, les participants s'entendaient tous pour dire que le système à carte numérique/télémètre laser représenterait un atout extrêmement précieux pour les soldats dans l'exécution de leurs tâches, pourvu que les problèmes relatifs à la taille, au poids et au câblage soient réglés de manière adéquate. La carte numérique à positionnement GPS intégrée au télémètre laser a permis d'améliorer et de rehausser considérablement les capacités des soldats d'infanterie dans l'exécution de leurs tâches de désignation d'objectifs.

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1. Background

Navigation and target designation are two critical operational functions required of the dismounted infantry soldier. During a reconnaissance (recce) patrol, soldiers in a section are required to navigate terrain and determine and communicate the location of various mission critical features and enemy positions. Current in-service methods require the recce section to estimate the target's location based on an estimate of their own location and a bearing and distance estimate to the target. Target location, direction of travel, and target descriptors can then be communicated in a contact report. If the information becomes essential for fire control, the precision and accuracy of range-to-target assessment becomes crucial. There are several concerns with the speed, precision, accuracy, and ease of performing this task with the in-service method. Various technologies are now available for greatly improving terrain navigation, target designation, automatically updating digital battlefield maps, and for communicating and disseminating this information.

Previous SIREQ-TD studies (FBES: Fort Benning Experimentation Series) have examined the implications of terrain navigation with a paper map and compass compared to a digital compass and Global Positioning System (GPS)-based digital map, which underlined performance enhancements in favour of a GPS–based digital map in the field (Kumagai and Massel, (2001), Kumagai and Tack, (2001), and Tack, Kumagai and Bos (2001)). Compared to the use of the digital conditions, the traditional terrain navigation with pacing, a paper map, and compass tended to be prone to error. Participants were observed to deviate from the track plan by hundreds of meters in some instances, while other participants even reversed their track bearings. These shortcomings were most evident during night operations where errors in distance and bearing estimation resulted in sizeable offset errors at waypoints and cumulatively at the objective. Soldiers were often quite wrong about their actual location on the map.

Therefore these sizable offset errors will also have a confounding effect on target designation tasks. With respect to situational awareness, it can only be assumed that if one does not accurately know their current location, then designating a target of interest will carry this offset error at the start of the designation process. Additionally, judging the distance and bearing to targets with the current in-service method, especially to distant targets, may further increase this inaccuracy. There are also several limitations with respect to communicating the location of this designated target by means of a contact report, which is currently sent verbally by radio. Aside from the time consuming aspect of using these traditional means, there may also be errors in reporting, and transcribing this message assuming that the transmitted message is being received.

Currently new technologies are becoming available that can address these limitations. GPS-based digital maps are available for providing accurate positional and navigational information, laser rangefinders with digital compasses can now be used to quickly and accurately judge bearing and distance to mission critical features, and digitally networked communications are increasing the speed and accuracy at which information can be transmitted over the battlefield.

To investigate the impact of these new technologies, this experiment examined the effect of using a geo-referenced digital map in conjunction with a new laser rangefinder and target designation software during target designation tasks, by empirically comparing the objective and subjective performance of soldiers to a compass and paper map baseline.

2. Objectives

This experiment assessed the following aims in order to establish whether the laser rangefinder in conjunction with a geo-referenced digital map and target designation software, would be an advantage for target designation tasks for the dismounted infantry soldier.

- Compare the speed and accuracy of the current in-service paper map, compass, and binocular method, for designating the location of target features on the battlefield, to the laser rangefinder conditions.
- Evaluate the speed and accuracy of using the laser rangefinder alone with a paper map as compared to using the laser rangefinder integrated with a geo-referenced digital map and target designation software.
- Identify the interface design issues associated with each target designation option and the associated implications of the computer interface design.
- Evaluate the effectiveness of alternative entity location reporting options.

3. Method

3.1. Overview

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

An eight-day field trial was undertaken at Fort Benning, Georgia over the period of 4-13 May 2004. Sixteen regular force infantry soldiers from the 3rd Battalion Princess Patricia Canadian Light Infantry (3PPCLI), based in CFB Edmonton, participated in these investigations. From three fixed locations, participants were required to designate the position of selected target features within specified zones (near, middle, far) using three target designation methods and report those locations. The three different methods were as follows:

1. Paper map, in-service compass, and binocular
2. Paper map, in-service compass, and laser rangefinder
3. Geo-referenced digital map, target designation software with forearm mounted tablet display, and integrated laser rangefinder

Three different fixed locations (A, B, C) were used to ensure that the learning effects of previous locations were minimized. Reference Figure 1. As well the presentations of conditions were balanced across all three methods, locations and distances to minimize any order effects.

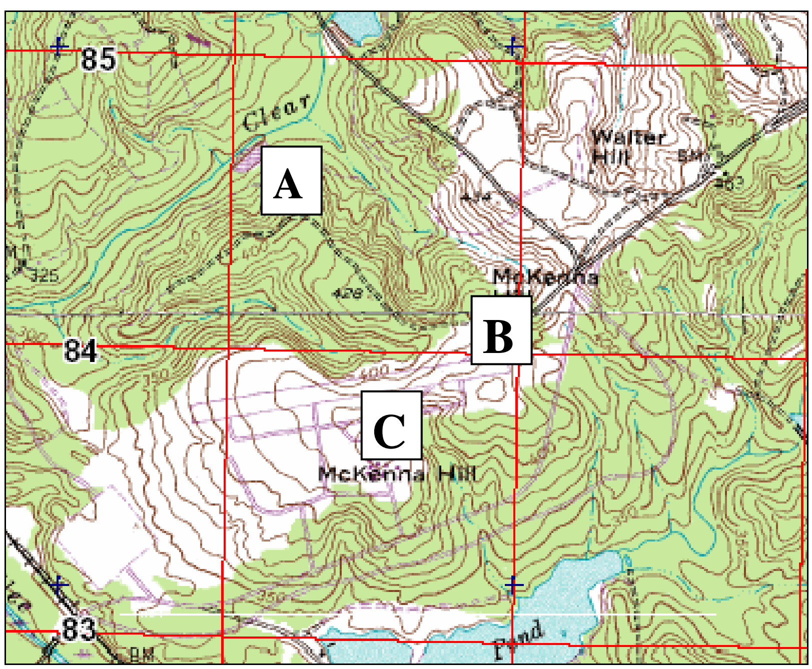

Figure 1: Location of Fixed Positions (A, B, C)

Human factors (HF) tests included performance measures as well as the subjective utility and usability measures of the three target designation conditions. Data collection included performance measures, questionnaires, HF observer assessments, and a focus group discussion.

3.2. Approach

All participants were first briefed on the goals, key features, and outline approach to the experiment. Participants were trained on each of the target designation methods (i.e. laser rangefinder and Xybernaut), and given 15 minutes to familiarize themselves.

From each of three predetermined locations (A, B, C), the participant was required to separately designate the location of selected target features in three specified zones: near target (approximately 0-500 m), middle target (approximately 500-1000 m), far target (approximately 1000-2000 m). The HF observer indicated to the participant the exact ten figure Military Grid Reference System (MGRS) of their location and indicated the near, mid and far target features in a sequential order once the previous task was complete. Given the MGRS coordinates of their location, the participant was instructed to provide the following:

1. The bearing to the target feature in mils (i.e. in-service compass, or the laser rangefinder).
2. The distance to the target feature in meters with the applicable device (i.e. binocular or the laser rangefinder).
3. Plot the location of the target feature on the map (using an eight-figure MGRS for the paper map condition).
4. The participant was then prompted to exchange this information with the HF observer.

Once the participant was ready to begin, a "GO" command was issued by the HF observer to signal the start and a stopwatch was initiated. At this command the participant positioned their binocular and began their target designation task (i.e. items 1-4 listed above). Upon reporting to the HF observer the location of the target feature with an eight-figure MGRS coordinate, the HF observer stopped the stopwatch. There was no time limit established for this task. Reference Figure 2.

Figure 2: Soldier using Leica Laser Rangefinder with Digital Map System

Mission performance measures such as the total time to determine bearing, distance and plotting the location of the target feature on the map as well as the overall accuracy were collected by the HF observer. These measures were recorded on a data sheet, and the target designation accuracy was then compared to actual GPS-referenced target locations. After the participant completed designating each of the near, mid and far targets for that particular location they were asked to fill out a Target Task Questionnaire and all mission data were logged and archived. The participant was then asked to proceed to the next location according to the order matrix.

Each of the sixteen participants completed the target designation task from different locations using three different target designation methods, in order to minimize any terrain learning effects between conditions and to achieve a balanced repeated measures within-subjects design. Each location was standardized for target difficulty, and configured to have as different terrain, topography, vegetation type and density as possible. Reference Figure 3.

Figure 3: Various Terrain Fort Benning, Georgia (L to R: location A, B, C)

At the completion of the experiment, participants were instructed to fill out a Target Exit Questionnaire, and a focus group was held to further discuss various issues, which were raised during the trial. Statistical differences were determined using a balanced, repeated-measures analysis of variance for the performance data as well as the subjective data. Furthermore, Duncan's post-hoc analyses were conducted on significant performance and subjective questionnaire data. Unless noted otherwise, the sample size for this experiment was n=16 and differences were identified at $p \leq 0.05$.

3.3. Equipment

The following section describes the in-service compass, baseline binocular condition, laser rangefinder, digital map computer system (Xybernaut), and target array.

3.3.1 In-Service Compass

Suunto MC-2G Global Sighting Compass: The in-service method of compass navigation was used in the paper map, compass, binocular and paper map, compass and Leica laser rangefinder conditions. The MC-2G compass featured a large, accurate mirror sight with a convenient sighting hole, plus a gimballed global needle, which levelled horizontally for correct alignment in any latitude zone on Earth (most compasses are balance only for a specific latitude zone). Reference Figure 4.

The compass weighed 65 g and had a liquid filled capsule that allowed for steady needle operation from -40°C to +60°C, luminescent bezel for night time use, self-cleaning bezel mechanism enabled smooth rotation, declination adjustment reduced the likelihood of error in correcting for declination, and a clinometer that measured slope angles.

Figure 4: Suunto MC-2G Global Sighting Compass

3.3.2 M-22 Baseline Binocular Condition

For the baseline condition the M-22 binocular was used. The M-22 7 x binocular provided a 50 m field of view at 1000 m and a reticle, graduated with a horizontal scale depicting 5-m increments at a range of 1000 m below the horizontal line and 5 m increments at 1000 m above the horizontal line. Reference Figure 5.

Figure 5: M-22 Baseline Binocular Condition

The M-22 binocular had the following specifications:

Magnification Power	7 X 50 binocular observation
Weight	1.22 kg
Other	Waterproof (1m, 60 min)

3.3.3 Laser Rangefinder

The Leica Geosystems AG laser range finding binocular was used for the partial and fully digital target designation tasks during this experiment. The Leica rangefinder provided a 120 m field of view at 1000 m and had the distance capability up to 2500 m under ideal conditions. Reference Figure 6.

Figure 6: Leica Laser Rangefinder Binocular

The Leica Geosystems laser rangefinder had the following specifications:

Magnification Power	7 X 42 binocular observation
Laser rangefinder	860 nm Class 1, eye safe laser EN 60825 (91) IEC 825 (90) ANSI Z 136.1 (93) FDA 21 CFR
Distance accuracy	$\pm$1m
Azimuth accuracy	$\pm$10mils ($\pm$0.6°)
Data Interface	RS232, uni-directional, ASCII standard, 1200 baud
Weight	1.7 kg
Other	Waterproof (1m, 10 min)

3.3.4 Soldier Computer and Digital Tablet

Xybernaut MA V®: With a range of display, input and wearability options, the Mobile Assistant V (MA V®) permitted the experimenters to personalize a configuration for the target designation investigation.

The MA V® was designed to be lightweight and rugged with core technologies that delivered the full functionality of a desktop PC. Reference Figure 7(L). The Intel Celeron, 500 MHz processor MA V® worked with a range of displays, wireless LAN, USB, PCMCIA, Firewire and RS232 devices. Xybernaut's Larissa flat-panel displays were daylight readable had touch pads for quick input and were built to handle rugged use**.** Reference Figure 7(R).

Figure 7: Xybernaut MA V® (L), Larissa Daylight Readable Display (R)

The Xybernaut MA V® had the following specifications:

Processor	Intel 500 MHz, 256 RAM
OS	Windows 2000 Professional
Ports	USB, VGA, 1394, PCMCIA, RS232
Weight (w/o holster)	455 g
Dimensions (w/o holster)	5.9 ”x 3.5 ”x 2 ”

3.3.4.1 Mapping Methods

The following mapping methods were used in this experiment: 2D Maps of terrain included a paper map (1:25,000 military scale) or a digital map displayed on a tablet. Reference Figure 8. The digital map provided the following additional capabilities, which were of interest:

- Zoom.
- Updated display of personal GPS location on map.
- Ability to interface with the Leica laser rangefinder binocular via the RS232 port, and automatically updated the location of the designated target.
- Ability to key in a contact report and to digitally submit that report.

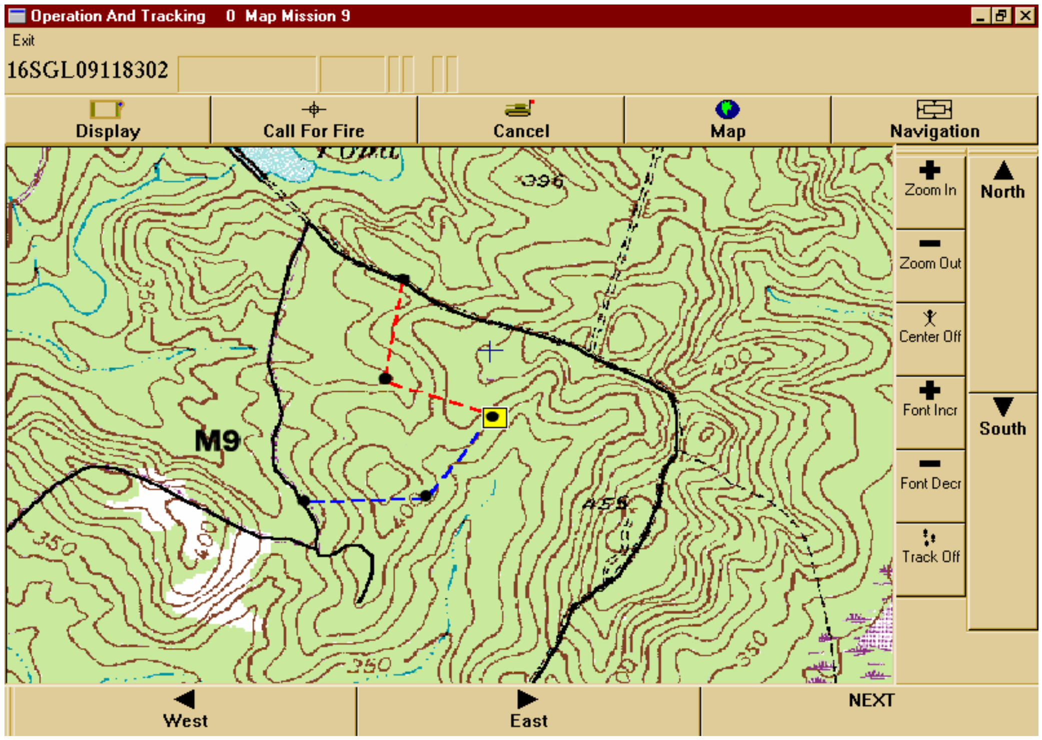

Figure 8: Example 2D Digital Map

3.3.5 Targets

Participants were required to designate an array of targets for this experiment. The targets consisted of plastic E ‘waffle’ targets, a truck tire, M-11 BTR front 1:2 target, M-2 BMP flank 1:2 target, M-6 BRDM flank 1:2 target, as well as radio, camera, and water towers. The targets were positioned from near (0-500 m), mid (500-1000 m) and far (1000-2000 m) distances. A sample of these targets is shown in Figure 9.

Figure 9: Sample Target Array

3.4. Participants

Sixteen regular force infantry soldiers participated from the 3rd Battalion Princess Patricia Canadian Light Infantry (3PPCLI) based in CFB Edmonton. The mean age of the participants were 23 years (s.d.=±2.5, max=29, min=19). The mean service in the regular forces was 2.61 years (s.d.=±1.34, max=6 years, min=2 months). The group consisted of two Corporals (12.5%) and fourteen Privates (87.5%). All sixteen participants had the necessary training and experience to designate targets.

3.5. Questionnaire Rating Scale

For the Target Exit Questionnaire, participants rated the acceptability of the equipment conditions on Navigation, Target Designation, Usability, Compatibility and the target designation System using the following seven-point scale. Reference Figure 10.

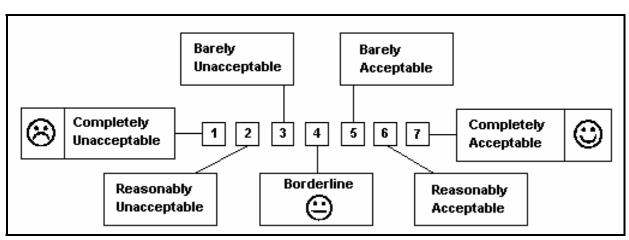

Figure 10: Standard Rating Scale

3.6. Limitations

This study had several limitations.

- M-22 binocular was 7 x 50 mm compared to the Leica laser rangefinder, which was 7 x 42 mm.
- Due to the accuracy of the GPS receivers (Garmin), the stitching together of the DeLorme map software, the ever-changing topography (i.e. erosion, change in foliage, construction of new roads) and age of the most current map (i.e. 1999), there may have been several sources of uncontrollable error that may have affected the results. However, the results reported in this experiment reflect the most accurate methods available to the experimenters at the time.

4. Results

4.1. Objective Performance Measures

Statistical analyses consisted of repeated measures ANOVA for the target designation conditions as well as the various locations. The dependent variables for the target designation component were the accuracy in distance to the targets (near, mid and far) and the time to complete the task. Differences were identified at $p \leq 0.05$ and unless otherwise noted the number of subjects was 16 for each of the three conditions (X = paper map, compass, and M-22 binocular; condition Y = paper map, compass, and Leica laser rangefinder; condition Z = digital map and Leica laser rangefinder). As well in the following graphs, a geometric shape denotes the objective means, the 'box' denotes ± 1 standard error, and the 'whiskers' denote ± 1 standard deviation.

4.1.1 Target Designation - Accuracy

The deviation in the absolute grid distance from the actual target location to the designated target location was used as an indicator of the effectiveness of the three conditions (X = paper map, compass, and M-22 binocular; condition Y = paper map, compass, and Leica laser rangefinder; condition Z = digital map and Leica laser rangefinder), as well as to verify any environmental/terrain conditioneffects (site A, B, C). For each participant and each condition, an absolute distance was calculated based on GPS readings from the exact location of the target assessed against the participant's reported location of the designated target.

4.1.1.1 Absolute Distance to Target

A significant effect was observed in terms of the deviation in distance from the actual target location to the participants designated target location for all of the site locations (A, B, C) between the three conditions (X, Y, Z), $F(2, 30)=8.59$, $p=.001$. Reference Figure 11. Duncan's post-hoc analysis showed that the error in distance from the true target location was the greatest for the baseline conditions (paper map, compass, and M-22 binocular), when compared to the other two conditions. Participants were more than twice as accurate using the two laser rangefinder conditions where the mean error in distance for the baseline condition was 247.32 ± 162.73 m, compared to 122.01 ± 136.06 m and 71.35 ± 56.84 m for condition Y and Z respectively. With respect to accuracy, there was no significant effect observed between the two laser rangefinder conditions.

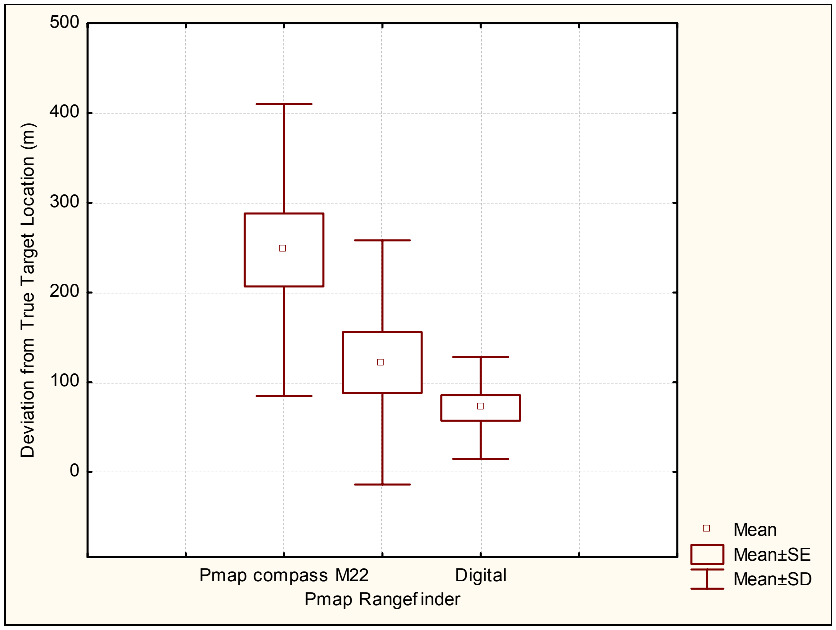

Figure 11: Target Designation Accuracy - Condition

When analyzing the deviation in distance from the actual target location (near, mid, far) to the participants designated target location for each of the three locations (A, B, C), the ANOVA failed to reach statistical significance at the .05 level (F(2, 30)=1.88, p = .17). Reference Figure 12.

There were no other environmental/terrain effects observed.

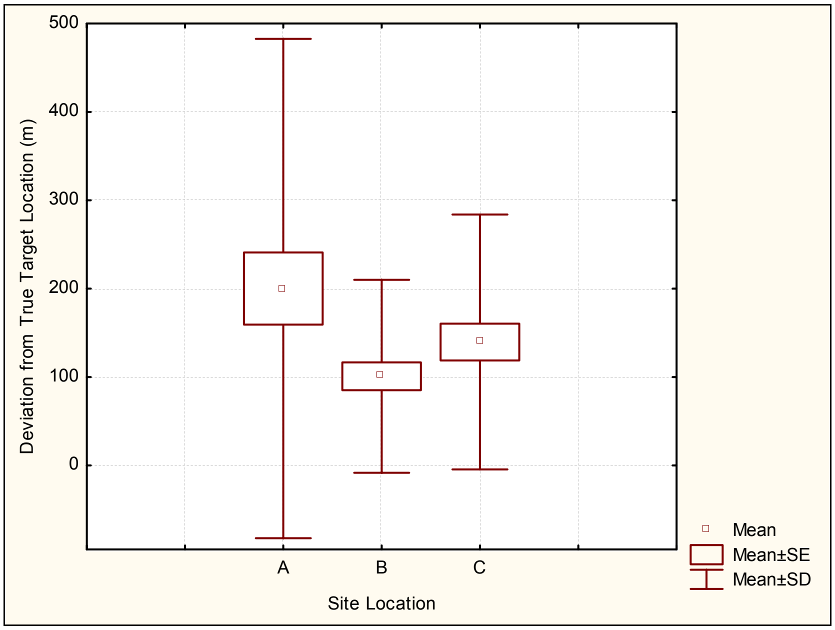

Figure 12: Target Designation Accuracy - Location

4.1.2 Target Designation - Time

The time required for the participants to designate and plot the location of the targets on the map (paper or GPS-based digital map) were used as an indicator of the time efficiency in target designation of the three methods (X = paper map, compass, and M-22 binocular; condition Y = paper map, compass, and Leica laser rangefinder; condition Z = digital map and Leica laser rangefinder), as well as to verify any environmental/terrain effects (site A, B, C). For each participant and each condition, the time was recorded.

4.1.2.1 Time to Designate Targets

A highly significant effect was observed in terms of the time to designate the location of near, mid and far targets for all of the site locations (A, B, C) between the three conditions (X, Y, Z), F(2, 30)=43.42, p=.000. Reference Figure 13. Duncan's post-hoc analysis showed that the fully digital condition (Z) resulted in the shortest duration to designate targets (115.75 ± 39.37 s), the paper map, compass and laser rangefinder condition (Y) was the second quickest method (206.4 ± 53.92), while the baseline condition (X) resulted in the slowest method to designate targets (306.90 ± 111.30 s). The difference between the fastest method and the slowest method to designate the location of the targets was greater than three minutes (191.15 s) or 165% slower. These findings were further enforced during focus group discussions where participants felt that the digital condition was the most efficient method of target designation in the field.

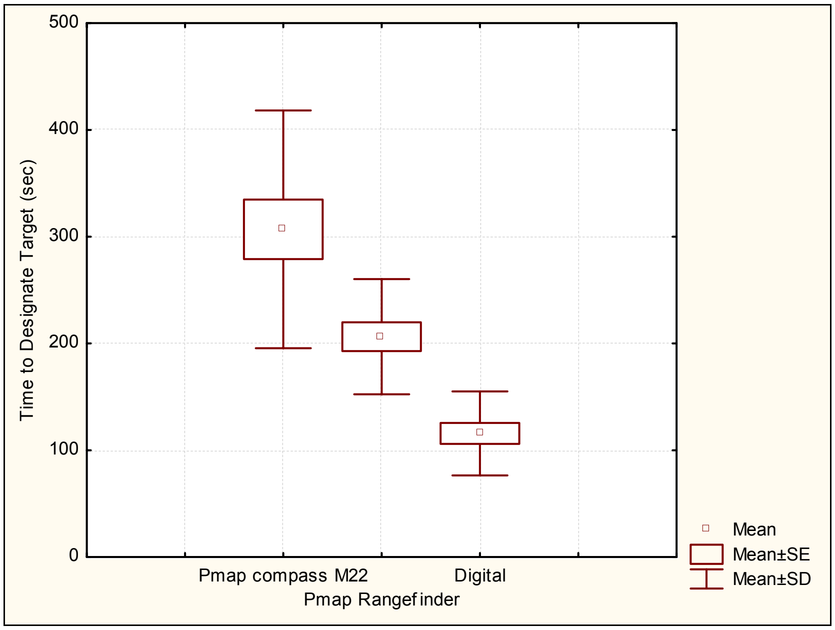

Figure 13: Time to Designate Targets

When analyzing the variance in time to designate the location of targets for all three conditions (X, Y, Z) between the three sites (A, B, C), the results of the ANOVA failed to reach statistical significance at the 0.05 level of confidence, $F(2, 30) = 0.94$, $p = .40$. Therefore there were no environmental/terrain effects observed between the three site locations.

4.2. Subjective Performance Measures

Subjective performance measures consisted of a Task Questionnaire and Exit Questionnaire. Statistical analyses consisted of repeated measures ANOVA between conditions. Duncan's post-hoc analyses were conducted on significant differences. Differences were identified at $p \leq 0.05$ for the 15 participants who responded to the Exit Questionnaire (i.e. one participant did not complete an Exit Questionnaire).

Unless otherwise noted on the following graphs, a geometric shape denotes the subjective mean, the 'box' denotes ± 1 standard error, and the 'whiskers' denote ± 1 standard deviation.

4.2.1 Exit Questionnaire

Participants rated the acceptability of the three conditions (X = paper map, compass, and M-22 binocular; condition Y = paper map, compass, and Leica laser rangefinder; condition Z = digital map and Leica laser rangefinder), for the 'Effectiveness for Navigation,' 'Effectiveness for Target Designation,' 'Usability,' 'Compatibility,' and 'Evaluation of System.' Additionally, the

'Evaluation of Software,' for condition C and strength, weakness and function agreement statements were rated by the participants for all three target designation conditions.

4.2.1.1 Effectiveness for Map Plotting

Participants rated the Effectiveness for Map Plotting across all three conditions (X, Y, Z) with the statements, 'Ease of locating own position on the map,' 'Time to determine own location (on the map),' and 'Accuracy of estimating own location (on the map).'

As well the participants rated the overall acceptability for the 'Overall Effectiveness of Map Plotting" across all three conditions.

4.2.1.1.1 Exit Ease of Locating Own Position on the Map

A highly significant effect was observed between the three target designation conditions in terms of the ease of locating own position on the map, $F(2, 28)=14.55$, $p=.000$. Reference Figure 14. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions. The participants' mean acceptability rating of condition Z was greater than "Reasonably Acceptable," whereas condition X and Y were rated between "Barely Acceptable" and "Reasonably Acceptable." There were no other significant effects.

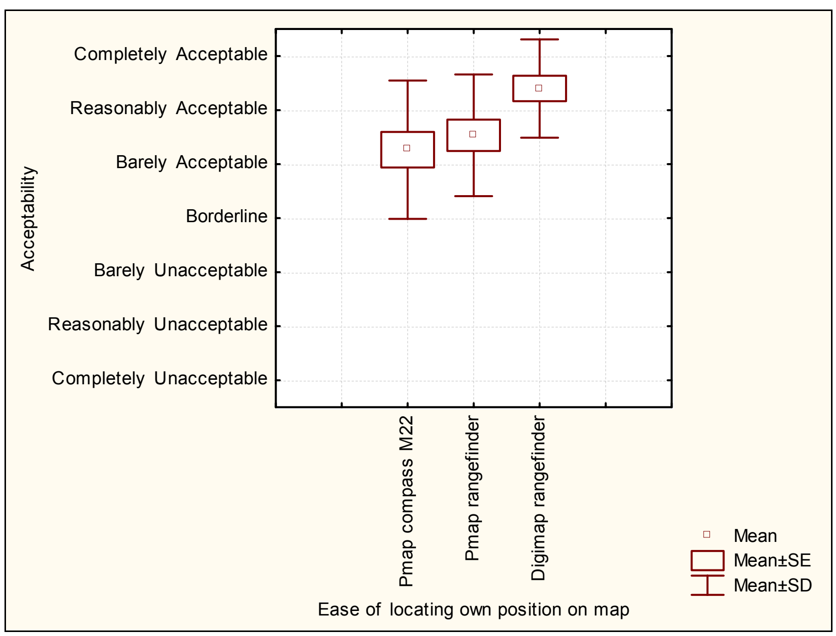

Figure 14: Ease of Locating Own Position on the Map

4.2.1.1.2 Time to Determine Own Location

A highly significant effect was observed between the three target designation conditions in terms of the time to determine own location, $F(2, 28) = 25.80$, $p = .000$. Reference Figure 15. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions. The participants' mean acceptability rating of condition Z was greater than "Reasonably Acceptable," whereas condition X and Y were rated between "Barely Acceptable" and "Reasonably Acceptable." There were no other significant effects.

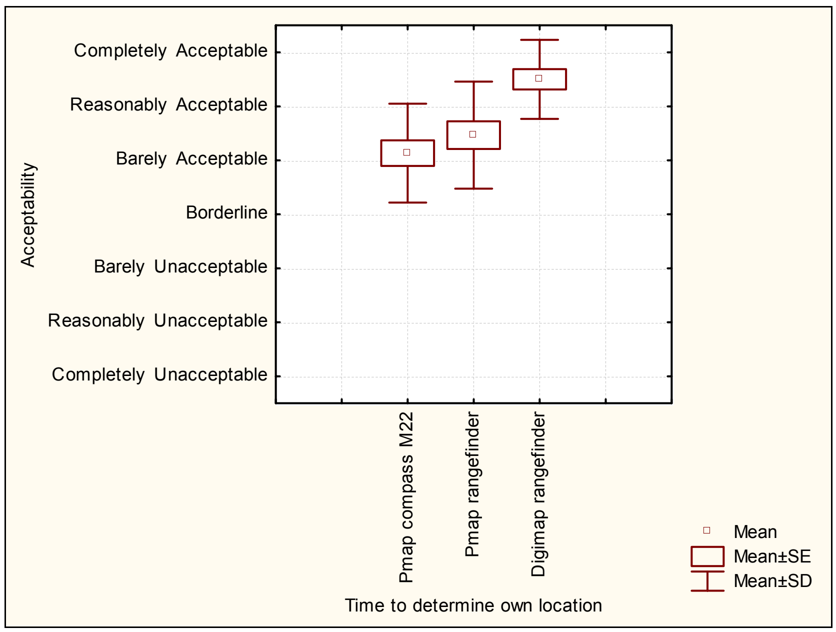

Figure 15: Time to Determine Own Location

4.2.1.1.3 Accuracy of Estimating Own Location

A highly significant effect was observed between the three target designation conditions in terms of the accuracy of estimating own location, $F(2, 28) = 9.83$, $p < .001$. Reference Figure 16. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions. The participants' mean acceptability rating of condition Z was greater than "Reasonably Acceptable," whereas condition X and Y were rated between "Barely Acceptable" and "Reasonably Acceptable." There were no other significant effects.

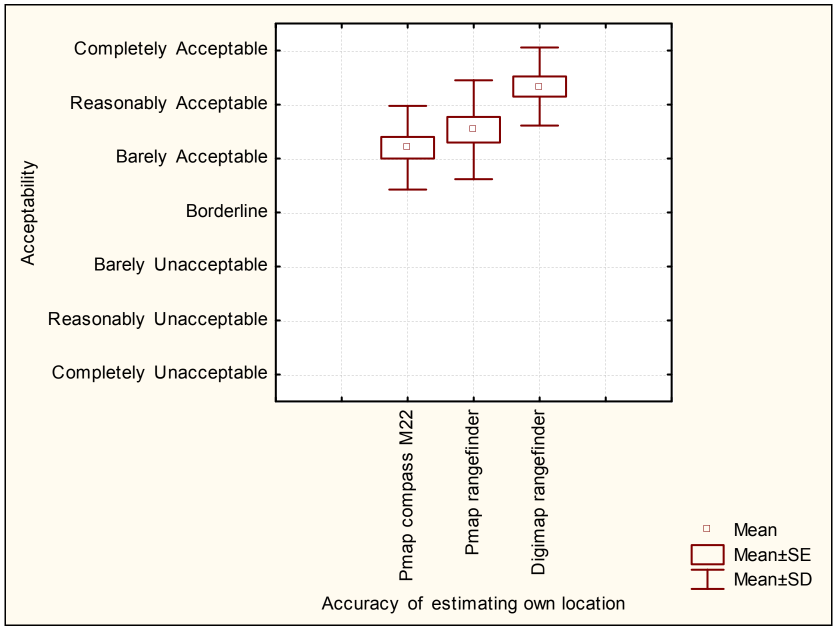

Figure 16: Accuracy of Estimating Own Location

4.2.1.1.4 Exit Overall Effectiveness of Map Plotting

When comparing the 'Overall Effectiveness of Map Plotting' variable and the three conditions, a highly significant effect was observed $F(2, 28)=13.79$, $p=.000$. Reference Figure 17. Duncan's post-hoc analysis showed that the GPS-based digital map condition was rated significantly higher in acceptability than the two paper map conditions. The participants' mean acceptability rating of the digital map condition was greater than "Reasonably Acceptable," whereas the other two conditions were rated between "Barely Acceptable" and "Reasonably Acceptable." Overall participants felt the digital map method of map plotting was the most acceptable means. This finding was reinforced by comments raised during the focus group discussions. No significant difference was observed between the two paper map conditions (conditions X and Y).

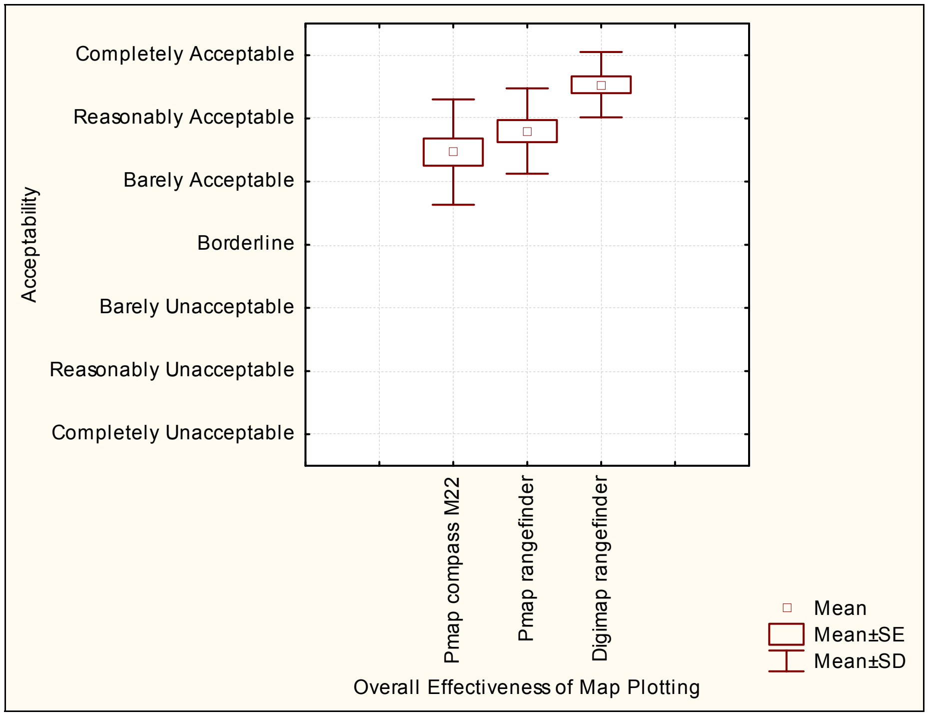

Figure 17: Overall Effectiveness of Map Plotting

4.2.1.2 Exit Effectiveness for Target Designation

Participants rated the Effectiveness for Target Designation across all three conditions (X, Y, Z) with the statements, 'Time to determine the bearing to enemy/friendly entities,' 'Accuracy of determining the bearing to enemy/friendly entities,' 'Time to determine the distance to enemy/friendly entities,' 'Accuracy of determining the distance to enemy/friendly entities,' 'Time to plot enemy/friendly entities,' and 'Accuracy of plotting enemy/friendly entities.'

As well the participants rated the overall acceptability for the 'Overall Effectiveness of Target Designation System' across all three conditions.

4.2.1.2.1 Exit Time to Determine the Bearing to Enemy/Friendly Entities

A highly significant effect was observed between the three target designation conditions in terms of the time to determine the bearing to enemy/friendly entities, $F(2, 28)=11.66$, $p<.001$. Reference Figure 18. Duncan's post-hoc analysis showed that the two conditions using the Leica laser rangefinder (Y and Z) were rated significantly higher in acceptability than the baseline condition (X). The participants' mean acceptability rating of the Leica laser rangefinder conditions was greater than "Reasonably Acceptable," whereas the baseline condition was rated between "Barely Acceptable" and "Reasonably Acceptable." Participants felt the time of acquiring the bearing was the most acceptable with the Leica laser rangefinder. There were no other significant effects.

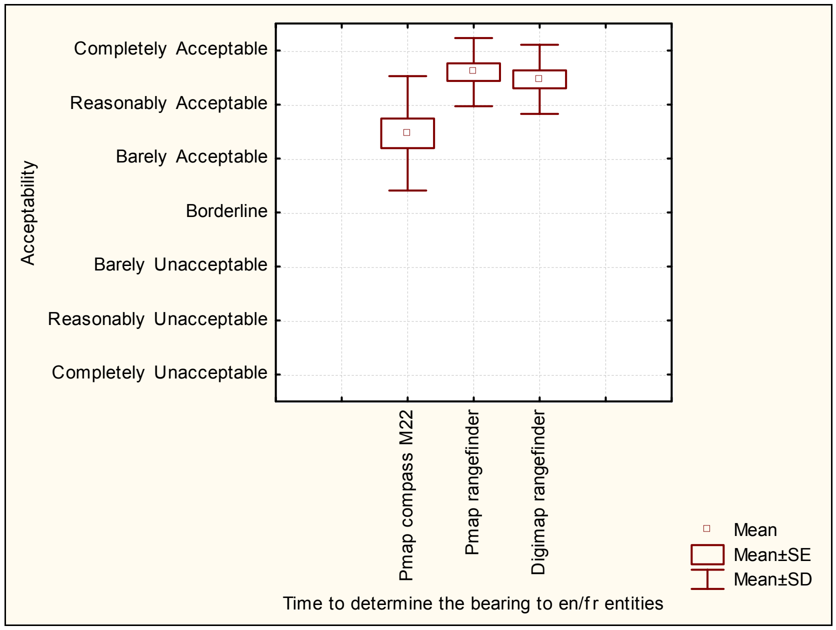

Figure 18: Time to Determine the Bearing to Enemy/Friendly Entities

4.2.1.2.1.1 Accuracy of Determining the Bearing to Enemy/Friendly Entities

A highly significant effect was observed between the three target designation conditions in terms of the accuracy of determining the bearing to enemy/friendly entities, $F(2, 28) = 17.43$, $p = .000$. Reference Figure 19. Duncan's post-hoc analysis showed that the two conditions using the Leica laser rangefinder (Y and Z) were rated significantly higher in acceptability than the baseline condition (X). The participants' mean acceptability rating of the Leica laser rangefinder conditions was greater than "Reasonably Acceptable," whereas the baseline condition was rated between "Barely Acceptable" and "Reasonably Acceptable." Participants felt the accuracy of acquiring the bearing was the most acceptable with the Leica laser rangefinder. There were no other significant effects.

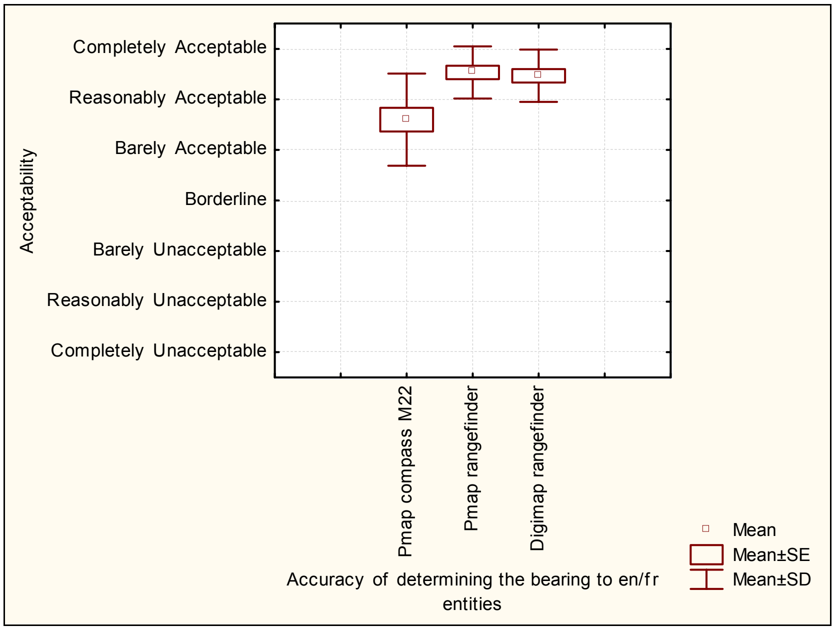

Figure 19: Accuracy of Determining the Bearing to Enemy/Friendly Entities

4.2.1.2.1.2 Time to Determine the Distance to Enemy/Friendly Entities

A highly significant effect was observed between the three target designation conditions in terms of the time to determine the distance to enemy/friendly entities, $F(2, 28)=24.65$, $p=.000$. Reference Figure 20. Duncan's post-hoc analysis showed that the two conditions using the Leica laser rangefinder (Y and Z) were rated significantly higher in acceptability than the baseline condition (X). The participants' mean acceptability rating of the Leica laser rangefinder conditions was greater than "Reasonably Acceptable," whereas the baseline condition was rated between "Barely Acceptable" and "Reasonably Acceptable." Participants felt the time to determine the distance to targets was the most acceptable with the Leica laser rangefinder. There were no other significant effects.

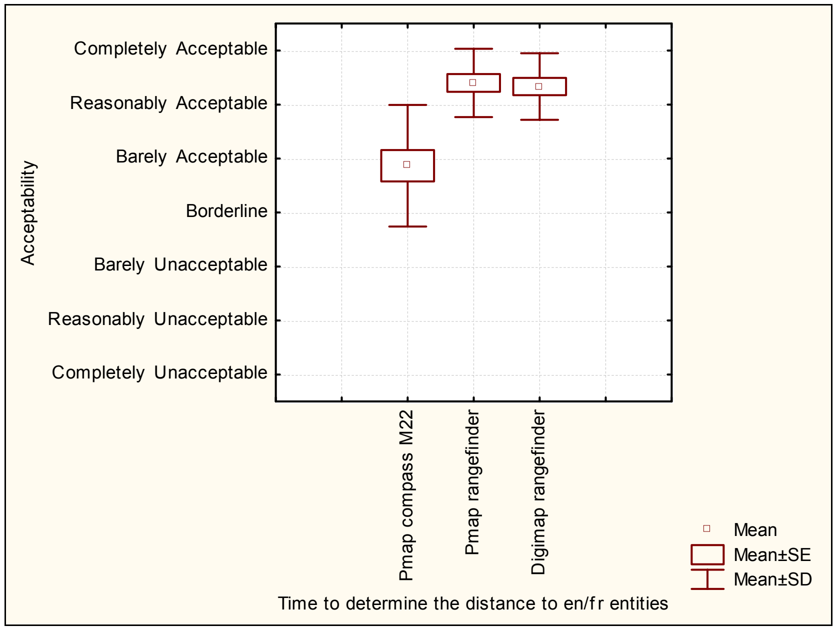

Figure 20: Time to Determine Distance to Enemy/Friendly Entities

4.2.1.2.1.3 Accuracy of Determining the Distance to Enemy/Friendly Entities

A highly significant effect was observed between the three target designation conditions in terms of the accuracy of determining the distance to enemy/friendly entities, $F(2, 28)=27.34$, $p=.000$. Reference Figure 21. Duncan's post-hoc analysis showed that the two conditions using the Leica laser rangefinder (Y and Z) were rated significantly higher in acceptability than the baseline condition (X). The participants' mean acceptability rating of the Leica laser rangefinder conditions was greater than "Reasonably Acceptable," whereas the baseline condition was rated between "Borderline" and "Barely Acceptable." Participants felt that they were much more accurate in designating targets using the laser rangefinder compared to the baseline condition. There were no other significant effects.

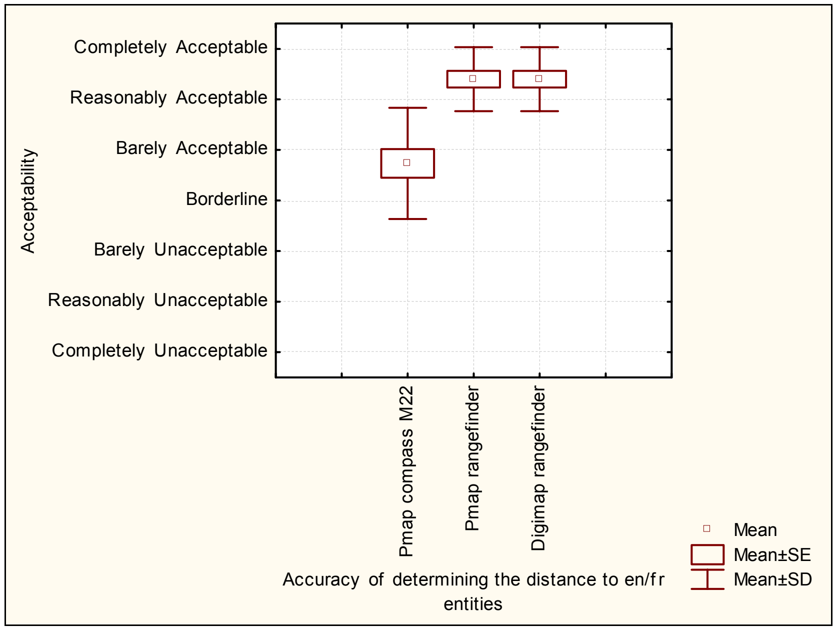

Figure 21: Accuracy of Determining the Distance to Enemy/Friendly Entities

4.2.1.2.1.4 Time to Plot Enemy/Friendly Entities

A highly significant effect was observed between the three target designation conditions in terms of the time to plot enemy/friendly entities, $F(2, 28)=29.03$, $p=.000$. Reference Figure 22. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions. The participants' mean acceptability rating of the digital condition was greater than "Reasonably Acceptable," whereas conditions X and Y were rated between "Borderline" and "Reasonably Acceptable." Using the digital condition the location of the enemy/friendly entities appeared instantaneously on the map, versus the two paper map conditions, which required participants to calculate and physically plot the location of the entities on the map. There were no other significant effects.

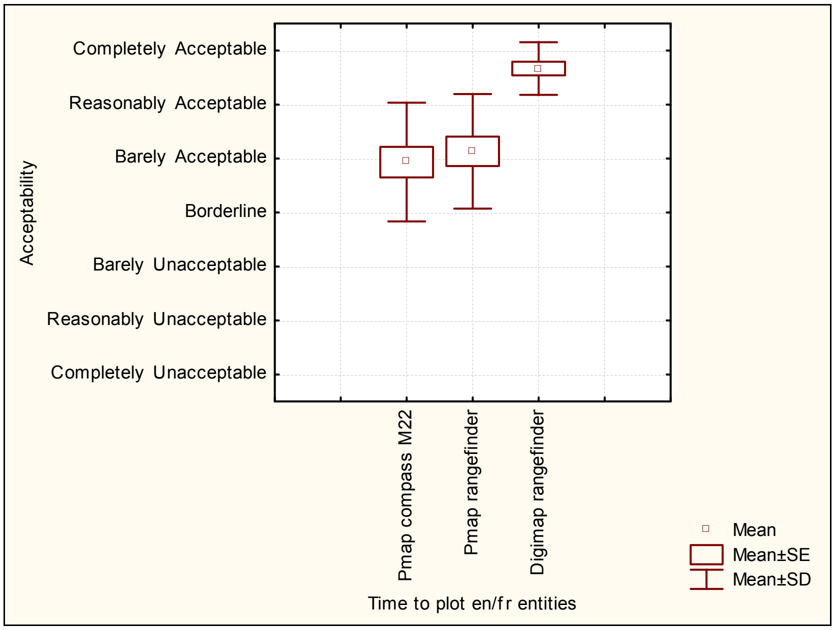

Figure 22: Time to Plot Enemy/Friendly Entities

4.2.1.2.1.5 Accuracy of Plotting Enemy/Friendly Entities

A highly significant effect was observed between the three target designation conditions in terms of the accuracy of plotting enemy/friendly entities, $F(2, 28)=17.80$, $p=.000$. Reference Figure 23. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions, and the paper map, compass and Leica laser rangefinder condition was rated higher in acceptability than the baseline condition. The participants' mean acceptability rating of the digital condition was greater than "Reasonably Acceptable," the paper map, compass, and Leica laser rangefinder condition was rated between "Barely Acceptable" and "Reasonably Acceptable," while the paper map, compass and M-22 binocular condition was rated less than "Barely Acceptable."

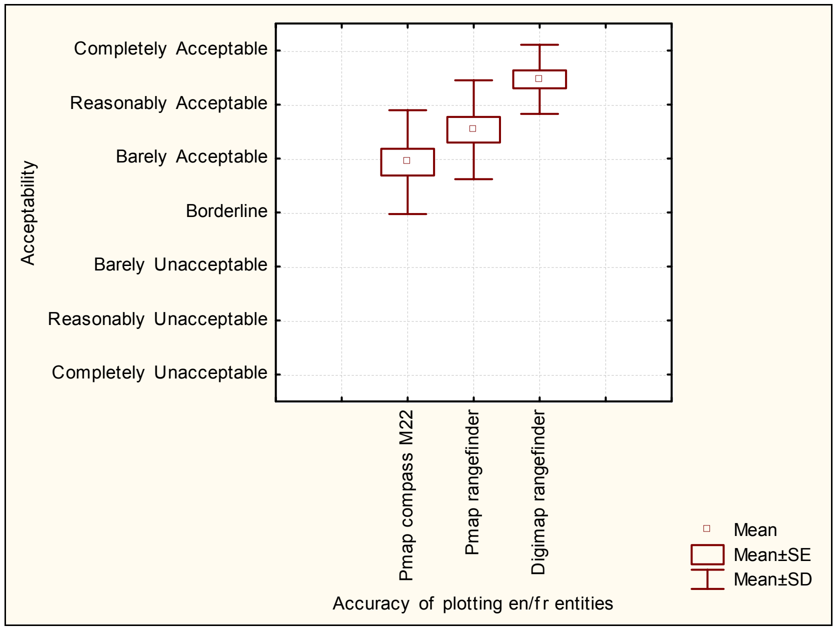

Figure 23: Accuracy of Plotting Enemy/Friendly Entities

4.2.1.2.1.6 Overall Effectiveness of Target Designation System

When comparing the 'Overall Effectiveness of Target Designation System' variable and the three conditions, a highly significant effect was observed, $F(2, 28)=19.99$, $p=.000$. Reference Figure 24. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions, and the paper map, compass and Leica laser rangefinder condition was rated higher in acceptability than the baseline condition. The participants' mean acceptability rating of the digital condition was greater than "Reasonably Acceptable," while the two paper map conditions were rated between "Barely Acceptable" and "Reasonably Acceptable." Overall participants felt that the digital map and Leica laser rangefinder condition was the most acceptable system for target designation followed closely by the paper map and Leica laser rangefinder condition. This finding was reinforced by comments voiced during the focus group discussion.

Figure 24: Overall Effectiveness of Target Designation System

4.2.1.3 Exit Usability

Participants rated the Usability across all three conditions (X, Y, Z) with the statements, 'Ease of learning the system,' and 'Ease of operating the system.'

As well the participants rated the overall acceptability for the 'Overall Usability' across all three conditions.

4.2.1.3.1 Ease of Learning the System

A significant effect was observed between the three target designation conditions in terms of the ease of learning the system, $F(2, 28) = 5.89$, $p < .008$. Reference Figure 25. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions. The participants' mean acceptability rating of the digital condition was equal to "Reasonably Acceptable," whereas the other two conditions were rated between "Barely Acceptable" and "Reasonably Acceptable." During the trial and focus group discussion most of the participants commented that as long as the digital system was operational it was very simple to learn and operate.

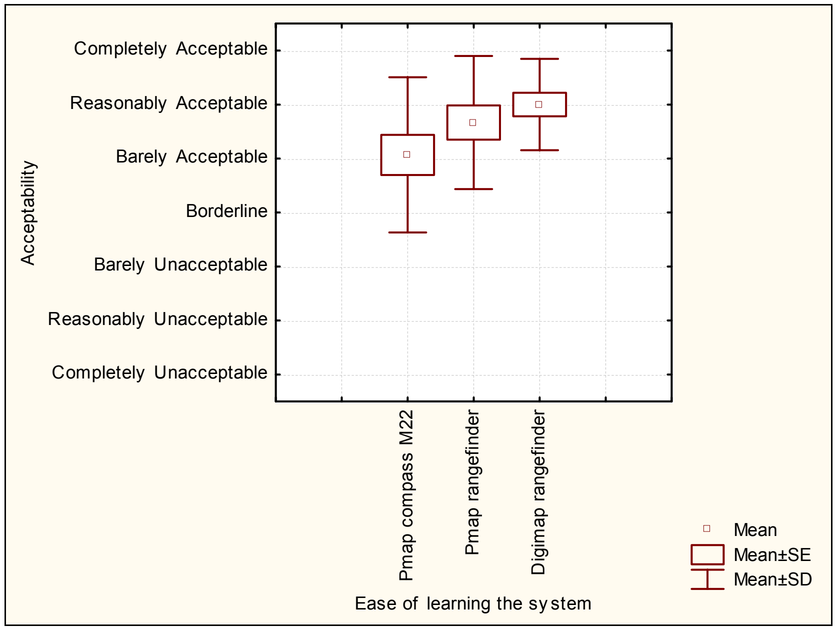

Figure 25: Ease of Learning the System

4.2.1.3.2 Exit Ease of Operating the System

A significant effect was observed between the three target designation conditions in terms of the ease of operating the system, $F(2, 28)=8.74$, $p<.002$. Reference Figure 26. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated significantly higher in acceptability than the other two conditions. The participants' mean acceptability rating of the digital condition was greater than "Reasonably Acceptable," whereas the other two conditions were rated equal to or greater than "Barely Acceptable" and less than "Reasonably Acceptable." During the trial and focus group discussion most of the participants commented that as long as the digital system was operational it was very simple to learn and operate.

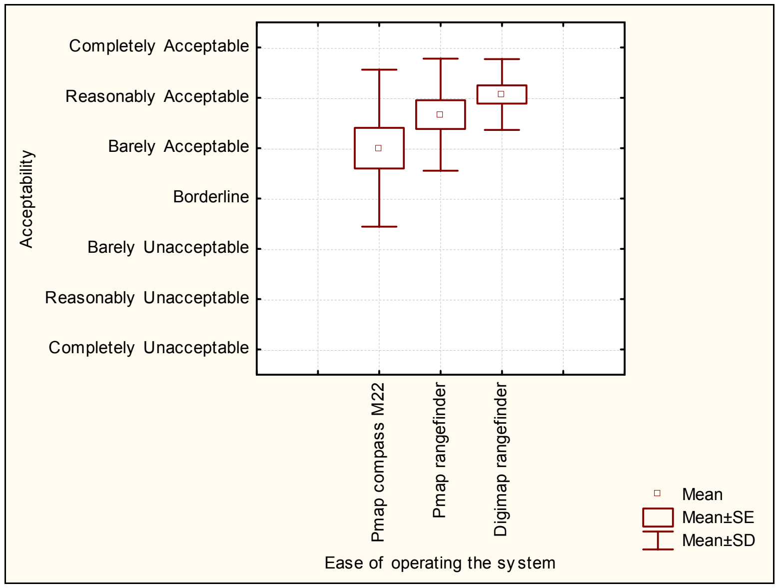

Figure 26: Ease of Operating the System

4.2.1.3.3 Overall Usability

When comparing 'Overall Usability' between the three conditions, the ANOVA failed to reach statistical significance at the 0.05 level of confidence. Reference Figure 27. The participants' mean acceptability rating of the digital condition was greater than "Reasonably Acceptable," and the other two conditions were rated between "Barely Acceptable" and "Reasonably Acceptable."

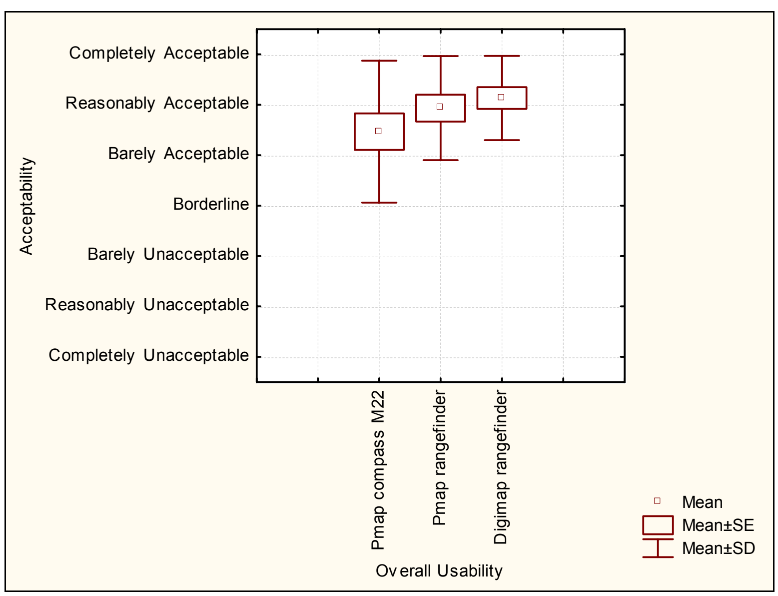

Figure 27: Overall Usability

4.2.1.4 Compatibility

Participants rated the Compatibility across all three conditions (X, Y, Z) with the statements, 'Compatibility (interference) with clothing,' and 'Compatibility (interference) with weapon.'

As well the participants rated the overall acceptability for the 'Overall Compatibility Rating' across all three conditions.

4.2.1.4.1 Compatibility (interference) with Clothing

A highly significant effect was observed between the three target designation conditions in terms of the compatibility (interference) with clothing, $F(2, 28)=19.65$, $p=.000$. Reference Figure 28. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition was rated the least acceptable system compared to the other two conditions. The paper map, compass and Leica laser rangefinder condition was rated slightly higher than the digital condition, while the baseline condition was the most accepted system in terms of compatibility. The participants' mean acceptability rating of the digital condition was between "Borderline" and "Barely Acceptable," the paper map, compass and Leica laser rangefinder was rated between "Barely Acceptable" and "Reasonably Acceptable," while the baseline condition was rated greater than "Reasonably Acceptable." During the trial and focus group discussion all of the participants commented that the extra cabling, size, weight, and added components to the systems using the Leica laser rangefinder were a nuisance, were not compatible with clothing and were often an obstruction.

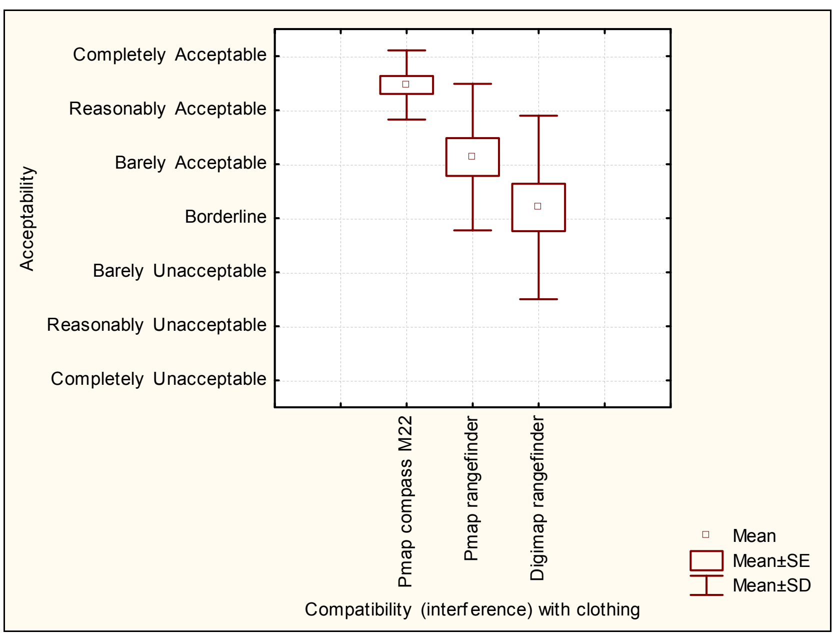

Figure 28: Compatibility (interference) with Clothing

4.2.1.4.2 Compatibility (interference) with Weapon

A highly significant effect was observed between the three target designation conditions in terms of the compatibility (interference) with weapon, $F(2, 28) = 11.99$, $p < .001$. Reference Figure 29. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition as well as the paper map, compass and Leica laser rangefinder condition were rated significantly lower in acceptability than the paper map, compass and M-22 condition. The paper map, compass and Leica laser rangefinder condition was also rated slightly higher in acceptability than the digital map condition ($p = .05$). The participants' mean acceptability rating of the digital condition was between "Borderline" and "Barely Acceptable," the paper map, compass and Leica laser rangefinder was rated between "Barely Acceptable" and "Reasonably Acceptable," while the baseline condition was rated greater than "Reasonably Acceptable." During the trial and focus group discussion all of the participants commented that the extra cabling, size, weight, and added components to the systems using the Leica laser rangefinder were a nuisance, were not compatible with their weapon and were often an obstruction.

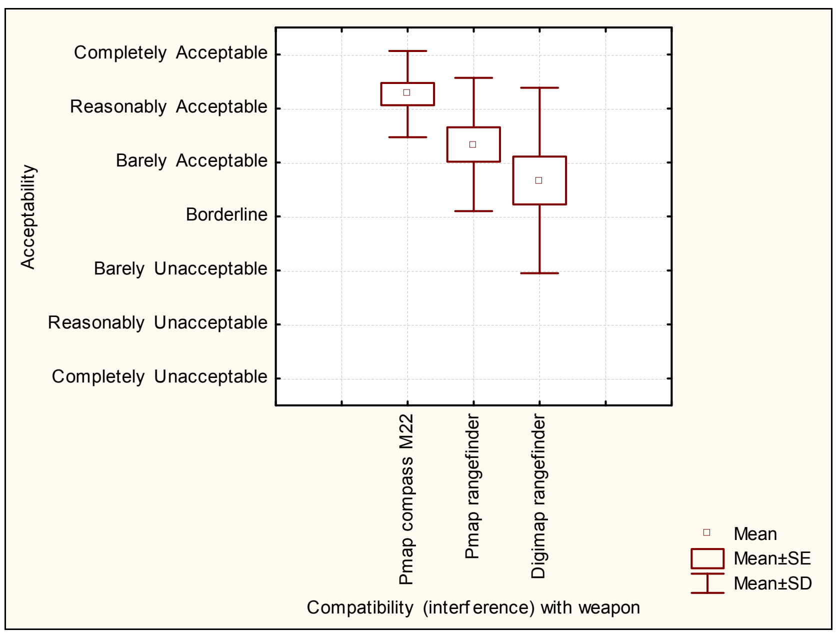

Figure 29: Compatibility (interference) with Weapon

4.2.1.4.3 Overall Compatibility Rating

When comparing the 'Overall Compatibility Rating' variable and the three conditions, a highly significant effect was observed $F(2, 28) = 15.11$, $p = .000$. Reference Figure 30. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition (Z) was rated significantly lower in acceptability than the other two conditions (X and Y), and condition Y was also rated significantly lower than the baseline condition. The participants' mean acceptability rating of the digital map and Leica laser rangefinder condition was less than "Barely Acceptable," the paper map, compass, and Leica laser rangefinder condition was rated between "Barely Acceptable" and "Reasonably Acceptable," whereas the paper map, compass, and M-22 binocular condition was rated greater than "Reasonably Acceptable." Participants felt that the digital map and Leica laser rangefinder condition was the least acceptable system when it came to the overall compatibility level, followed closely by the paper map, compass and Leica laser rangefinder condition.

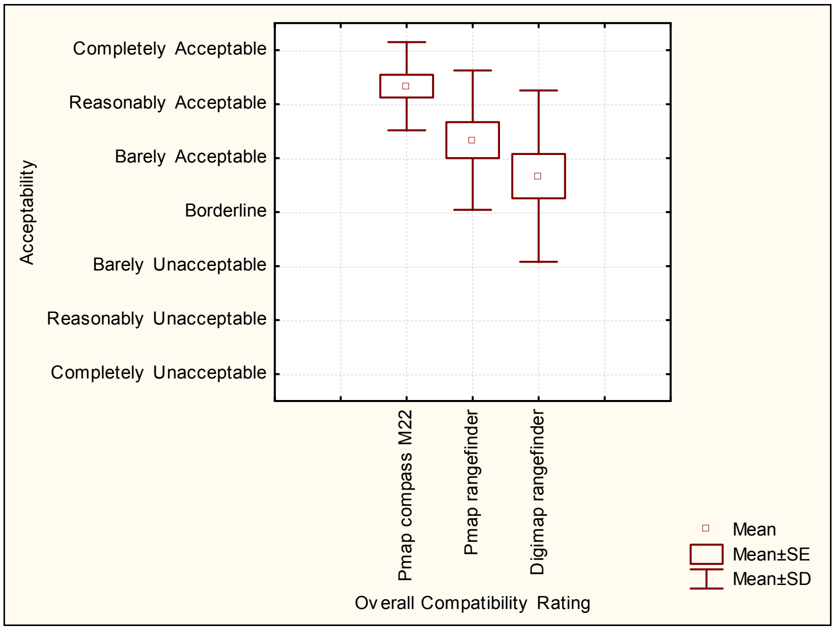

Figure 30: Overall Compatibility Rating

4.2.1.5 Evaluation of System

Participants rated the Evaluation of the System across all three conditions (X, Y, Z) with the statements, 'Confidence in the system,' 'Mental workload,' 'Ease of communicating enemy/friendly entity location,' 'Tactical feasibility,' 'Accuracy of the system,' and 'Durability of the system.'

4.2.1.5.1 Confidence in the System

No significant effect was observed between the three target designation conditions in terms of the confidence in the system, $F(2, 28)=1.26$, $p=.30$. The participants' felt similar levels of confidence with all three conditions where the mean acceptability ratings were between "Barely Acceptable" and equal to and less than "Reasonably Acceptable." The acceptability ratings were fairly high across all three conditions.

4.2.1.5.2 Mental Workload

A highly significant effect was observed between the three target designation conditions in terms of mental workload, $F(2, 28)=21.34$, $p=.000$. Reference Figure 31. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition (Z) was rated significantly higher in acceptability than the other two conditions (X and Y), and condition Y was also rated significantly higher in acceptability than condition X. The participants' mean acceptability rating of the digital map and Leica laser rangefinder condition was greater than

"Reasonably Acceptable," the paper map, compass, and Leica laser rangefinder condition was rated between "Barely Acceptable" and "Reasonably Acceptable," whereas the paper map, compass, and M-22 binocular condition was rated less than "Barely Acceptable."

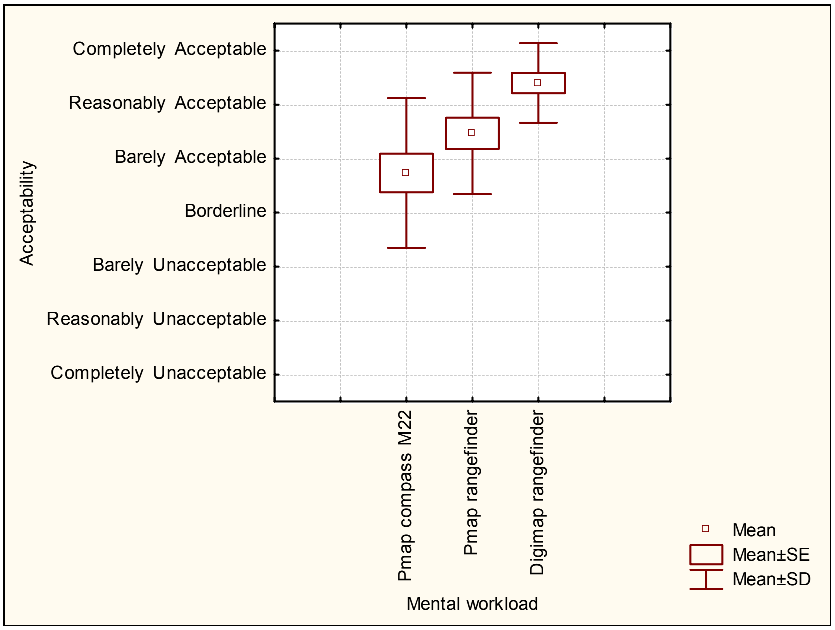

Figure 31: Mental Workload

4.2.1.5.3 Ease of Communicating Enemy/Friendly Entity Location

A highly significant effect was observed between the three target designation conditions in terms of the ease of communicating enemy/friendly entity location, $F(2, 28)=27.57$, $p=.000$. Reference Figure 32. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition (Z) was rated significantly higher in acceptability than the other two conditions (X and Y). The participants' mean acceptability rating of the digital map and Leica laser rangefinder condition was greater than "Reasonably Acceptable," the paper map, compass, and Leica laser rangefinder condition was rated between "Barely Acceptable" and "Reasonably Acceptable," whereas the paper map, compass, and M-22 binocular condition was rated less than "Barely Acceptable." Participants commented that communicating the location of the enemy/friendly location with the digital condition was quick and instantaneous, and would alleviate soldiers having to radio the 'spot report' which could lead to errors and security issues.

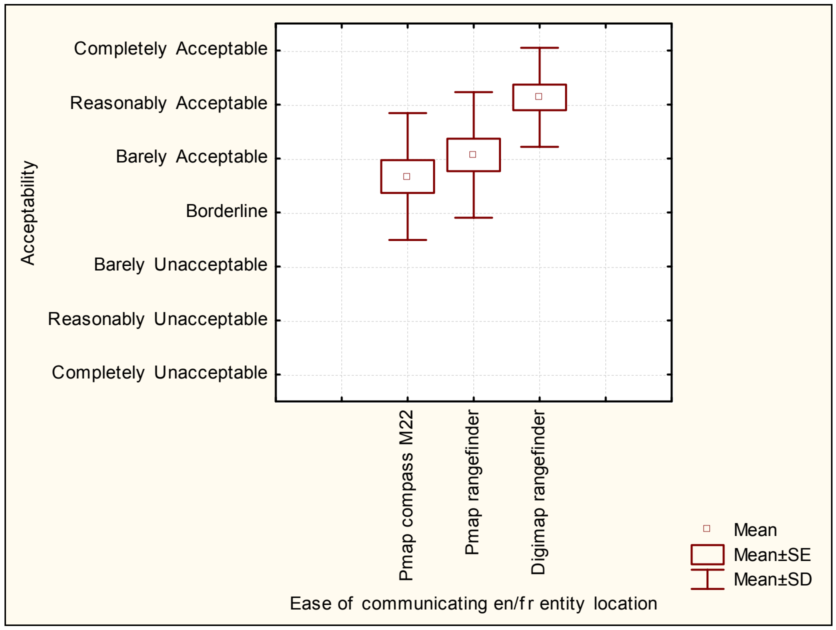

Figure 32: Ease of Communicating Enemy/Friendly Entity Location

4.2.1.5.4 Tactical Feasibility

A significant effect was observed between the three target designation conditions in terms of the tactical feasibility, $F(2, 28)=8.30$, $p=.001$. Reference Figure 33. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition (Z) was rated significantly lower in acceptability than the baseline condition (X). The baseline condition was also rated higher in acceptability than the paper map, compass, and Leica laser rangefinder condition (Y), and condition Y being rated higher in acceptability than the condition Z ($p=.05$). The participants' mean acceptability rating of the baseline condition was greater than "Reasonably Acceptable," the paper map, compass, and Leica laser rangefinder condition was rated between "Barely Acceptable" and "Reasonably Acceptable," whereas the digital map and laser rangefinder condition was rated equal to "Barely Acceptable." From a tactical standpoint, participants commented that the concept of the GPS-based digital map and laser rangefinder condition was important, however, in the current configuration (i.e. cabling issues, size, weight, numerous components, and power issues), it would not be feasible in the field.

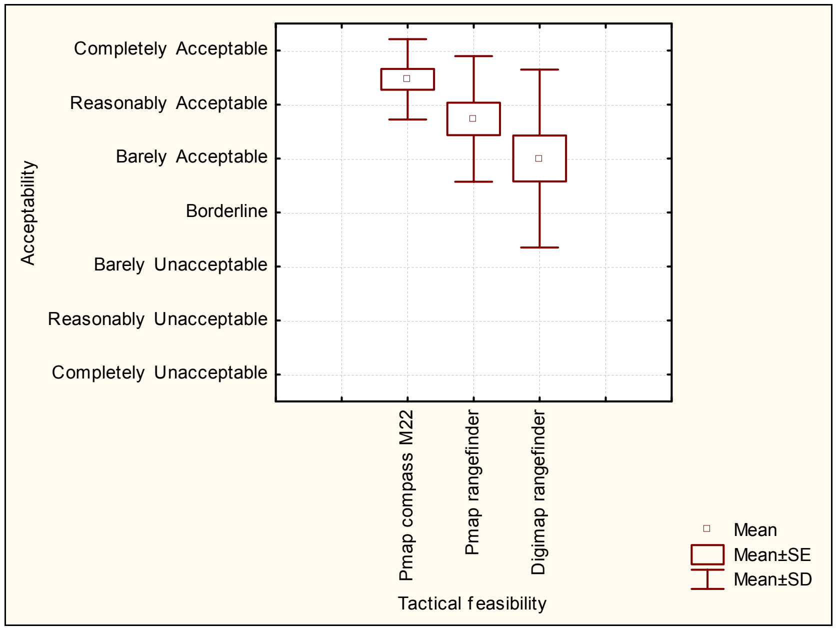

Figure 33: Tactical Feasibility

4.2.1.5.5 Accuracy of the System

A highly significant effect was observed between the three target designation conditions in terms of the accuracy of the system, $F(2, 28) = 12.67$, $p < .001$. Reference Figure 34. Duncan's post-hoc analysis showed that the two Leica laser rangefinder conditions (Y and Z) were rated significantly higher in acceptability than the baseline condition (X). The participants' mean acceptability rating of the two Leica laser rangefinder conditions was greater than "Reasonably Acceptable," whereas the baseline condition was rated between "Barely Acceptable" and "Reasonably Acceptable."

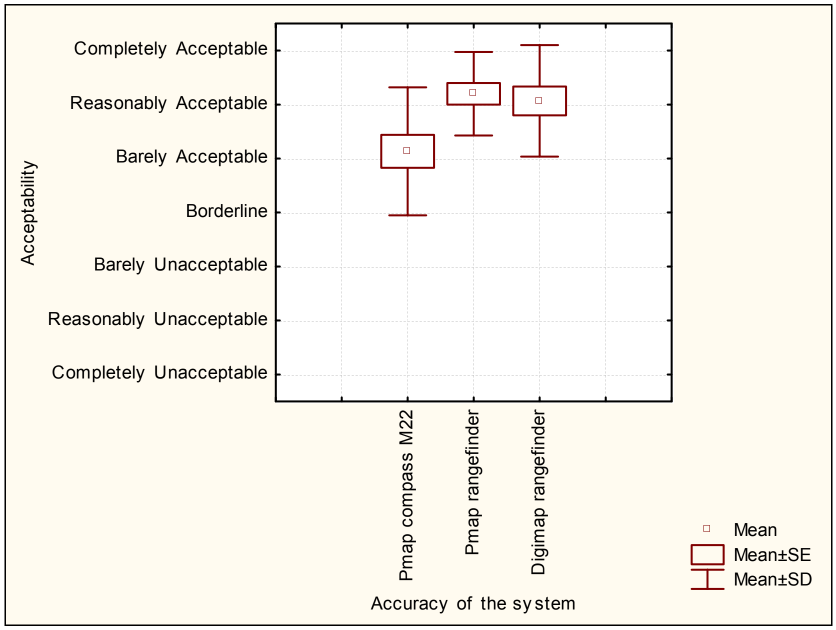

Figure 34: Accuracy of the System

4.2.1.5.6 Durability of the System

A highly significant effect was observed between the three target designation conditions in terms of the durability of the system, $F(2, 28) = 12.90$, $p < .001$. Reference Figure 35. Duncan's post-hoc analysis showed that the GPS-based digital map and Leica laser rangefinder condition (Z) was rated significantly lower in acceptability than the other two conditions (X and Y). The participants' mean acceptability rating of the baseline condition was greater than "Reasonably Acceptable," the paper map, compass, and Leica laser rangefinder condition was rated between "Barely Acceptable" and "Reasonably Acceptable," whereas the digital map and laser rangefinder condition was rated less than "Barely Acceptable." Although participants commented that the current configuration, especially with the digital condition, was not durable they realized that it was only a prototypical system.

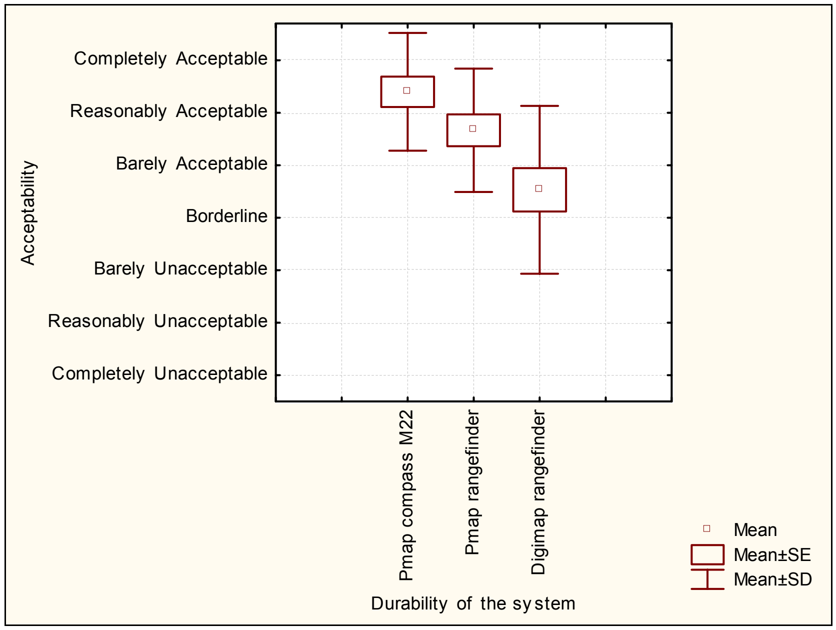

Figure 35: Durability of the System

4.2.1.6 Overall Acceptability of System

Participants rated the Overall Acceptability of the System across all three conditions (X, Y, Z).

4.2.1.6.1 Overall Acceptability of System

No significant effect was observed, in terms of the overall acceptability of the system and the three conditions, $F(2, 28)=.25$, $p=.78$. Reference Figure 36. The participants' felt that overall the three systems tested were of similar acceptability, where the participants' mean ratings were between "Barely Acceptable" and "Reasonably Acceptable."

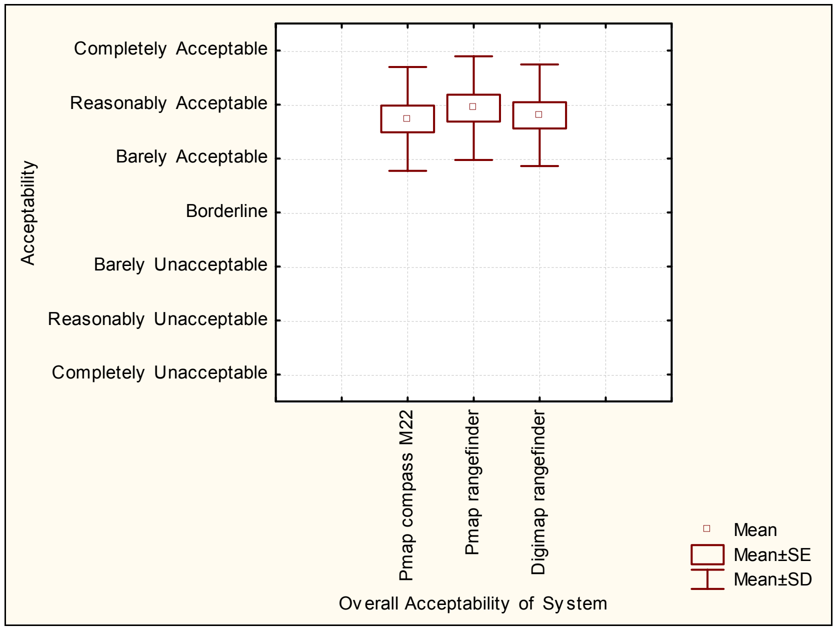

Figure 36: Overall Acceptability of System

4.2.1.7 Evaluation of Software

Participants evaluated the acceptability of the various elements of the software with the statements, 'Ease of using the software with the Leica Vector,' 'Ease of inputting information,' 'Ease of information recall,' 'Time to input enemy/friendly entities,' 'Accuracy of inputting enemy/friendly entities,' and 'Ability to change inputted information.' Participants also rated the 'Overall Acceptability of the Target Designation Software.'

When looking at the acceptability ratings for all six statements, participants evaluated all of the software issues to be greater than "Barely Acceptable". Reference Figure 37.

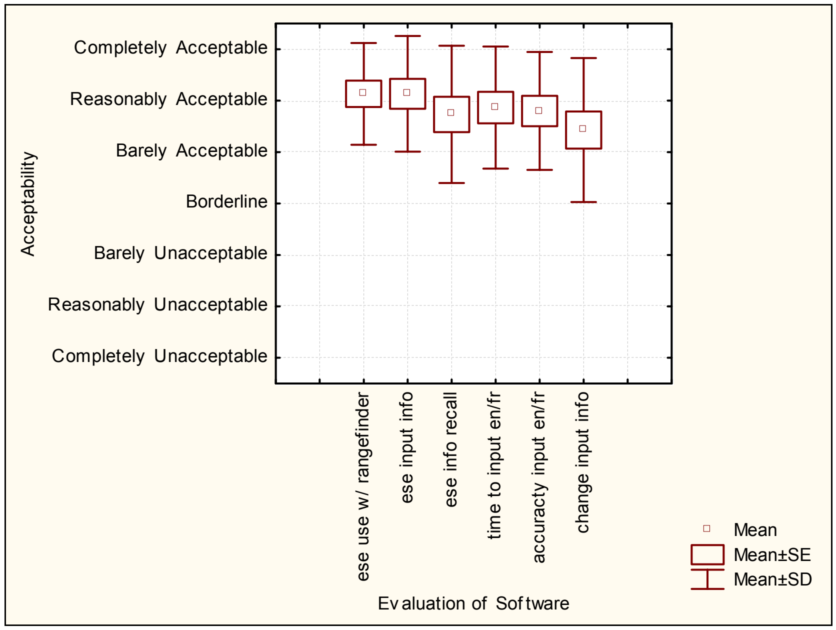

Figure 37: Evaluation of Software

Similarly, participants rated the 'Overall Acceptability of the Target Designation Software' in the digital map and Leica Vector condition to be greater than barely acceptable but less than reasonably acceptable. In the focus group discussions participants commented positively on many aspects of the software (i.e. ease of use, automatically updating the location of the entity on the map), but also raised warnings about over-reliance on the system.

4.2.1.8 Agreeability Statements

Participants rated their agreement with the following eight statements on a progressive scale of 1 to 7 (Strongly Disagree=1, Reasonably Disagree=2, Barely Disagree=3, Neutral=4, Barely Agree=5, Reasonably Agree=6, and Strongly Agree=7). Reference Table 1. The participants' combined scaled ratings (1 to 7) were tabulated, and means computed and analysed for each group.

Table 1: Agreeability Statements

S1	'I am more aware of my own location using the in-service map and compass system compared to the digital map system.'
S2	'I am able to navigate equally well regardless of the various navigation systems.'
S3	'I find it easier to use the Leica Vector for determining bearing and distance compared to the in-service map and compass system.'
S4	'I find it easier to use the paper map compared to the digital map condition when plotting the location of the enemy/friendly entity.'
S5	'I find it faster to use the digital map condition when plotting the location of the enemy/friendly entity.'
S6	'I find it to be more accurate in using the paper map compared to the digital map condition when plotting the location of the enemy/friendly entity.'
S7	'I find the automated reporting system of enemy/friendly entities to be more accurate than the in-service method.'
S8	'The paper map and Leica Vector system is the most accurate system.'

Overall participants were fairly neutral (greater than "Barely Disagree" but less than "Barely Agree") in terms of situational awareness, navigating and the ease and accuracy in plotting the location of the enemy/friendly entities using all three conditions. However, participants were in moderate agreement (between "Barely Agree" and "Reasonably Agree") that the digital map condition was fast in plotting the location of entities and more accurate in reporting those details. As well, participants were in strong agreement that the laser rangefinder condition was the easiest for determining the bearing and distance to entities. Reference Figure 38.

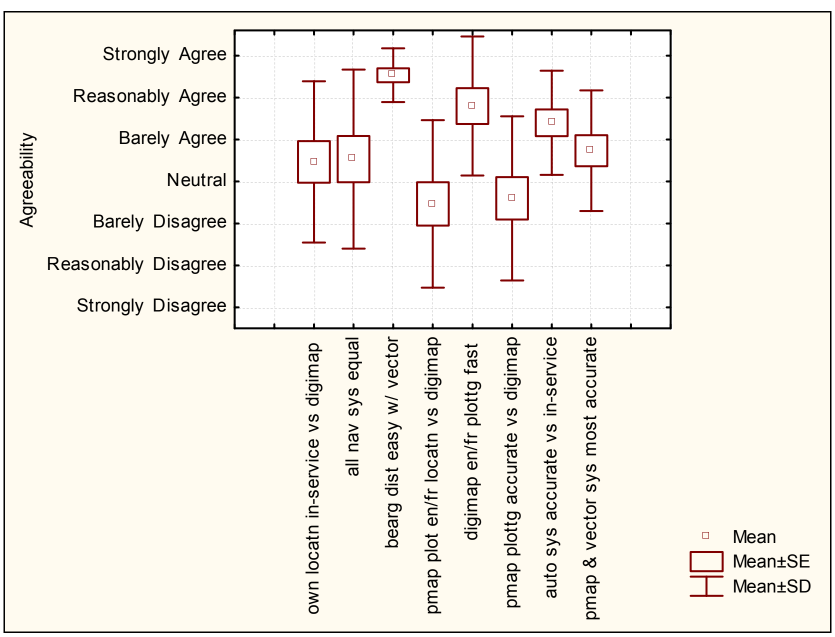

Figure 38: Agreeability Statement

5. Discussion

Terrain navigation and target designation are two critical operational functions required of the dismounted infantry soldier. The speed, precision, accuracy, and ease of performing this task with the current in-service methods are a concern and previous navigation studies have identified several areas for improvement. One concern involves the potential for large offset errors in target designation due to inaccuracies in determining one's own location on the map. When "own location" error was combined with any errors associated with the target designation task using conventional in-service means, these concerns would be compounded. To investigate the impact of new technologies on the target designation task, this experiment examined the effect of using a geo-referenced digital map in conjunction with a laser rangefinder and target designation software, by empirically comparing the objective and subjective performance of soldiers to a compass and paper map baseline.

Findings from this experiment demonstrated that the use of the laser rangefinder, when used alone with the paper map or when integrated with the GPS-based digital map, was more effective and efficient than the current in-service means (i.e. paper map, compass, and M-22 binoculars). The objective results showed that participants were more than twice as accurate using the laser rangefinder in designating targets as compared to the baseline condition. When designating near (0-500 m), mid (500-1000 m), and far (1000-2000 m) targets, participants were on average 125 m more accurate when using the laser rangefinder alone with the paper map, and 175 m more accurate when using the laser rangefinder integrated with the GPS-based digital map. With respect to the speed in designating targets, the digital condition was 1.5 minutes faster (90.65 s) than the paper map, compass and laser rangefinder condition, and more than 3 minutes faster (191.15 s) than the baseline condition.

Subjective findings from questionnaire data and focus group discussions also confirmed that participant's perceived the accuracy of the laser rangefinder, and the associated reduction in time to determine an accurate bearing and distance to target entities, to be a significant improvement over current methods. Participants were less confident in their ability to "eye-ball" targets in the distance with binoculars especially when visual cues and terrain to the target was obscured. While the laser rangefinder proved very effective in minimizing bearing and distance estimation error, this technology alone did not address concerns with errors in determining "own location" nor did it reduce plotting and reporting time.

Participants recognized that their ability to determine their own location on the map directly affected the accuracy with which targets could be designated on the map. In some cases, even when taking the necessary care and time, soldiers made serious errors in plotting their targets on the map. In one instance, a participant accidentally plotted the bearing to a target as a back bearing on the paper map. When the error was pointed out the participant acknowledged that they would have not committed this error with a digital system. Participants reported that the digital map/laser rangefinder system was a significant improvement over paper map methods for the accuracy and time required to plot target entities on the map. As well, targets plotted on the digital map could be easily transmitted as a report on a digital battlefield network, thereby reducing the risk of errors due to radio transfer and transcription. Participants indicated that the GPS-based digital map and laser rangefinder system was easy to learn and operate, and was the most efficient and most preferred method in plotting and reporting the location of the target entities on the map due to the low mental workload required and the instantaneous updating of the entities on the digital map.

However, participants reported concerns with the compatibility, durability, and tactical suitability of the experimental system used to test the digital map/laser rangefinder combination. Participants indicated that the exposed cabling/wiring, and the bulk and weight of the system, introduced some incompatibilities with existing clothing, weapons, and equipment. They suggested that any future system needed to be much more rugged, lighter and smaller, with no snagging hazards before it would be considered tactically feasible.

Other concerns included the power demands of any such system, the need for battery/power recharging or resupply, and the requirement for a spare parts logistics chain. Given the possibility of technology failure and the loss of GPS signals, participants emphasized the need to maintain their perishable, traditional map and compass skills. The traditional paper map and compass may not be the most efficient or accurate method but its strength lies in its lack of dependency on technology and power sources. Participants were also concerned about detectability by the enemy when using a laser rangefinder. While lasing non-vehicle targets is practical, most vehicles now have laser detection capabilities that could detect the emissions by the laser rangefinder and give their position away to the enemy.

Even with these limitations, participants unanimously agreed that the digital map/laser rangefinder system would be an extremely valuable addition to soldiering capabilities, if issues associated with size, weight, and cabling could be adequately addressed. The GPS-based digital map integrated with the laser rangefinder greatly improved and enhanced the capabilities of target designation tasks for the infantry soldier. However, participants recommended that such a system need only be issued to specific individuals in a platoon; for example, Platoon Commander, 2 IC, Reconnaissance Platoon, and artillery call signs.

6. References

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C. Tack, D. W., Kumagai, J. K., Bos, J. (2005). Alternative methods of providing survey and route information during open country terrain navigation. *Defence Research and Development Canada – Toronto, Report No. CR2005-015.*

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(U) An eight−day field trial was undertaken at Fort Benning, Georgia to investigate the impact of new technologies on the target designation task. This experiment compared the objective and subjective performance of soldiers using three conditions: a compass and paper map baseline; a paper map with a laser rangefinder; and a geo−referenced digital map in conjunction with a laser rangefinder and target designation software.

Findings from this experiment demonstrated that the laser rangefinder, used either with the paper map or integrated with the GPS−based digital map, was more effective and efficient than the current in−service means (i.e. paper map, compass, and M−22 binoculars). The objective results showed that participants were more than twice as accurate using the laser rangefinder in designating targets as compared to the baseline condition. The digital map/laser rangefinder system was also much faster than the other two conditions at designating targets.

Participants recognized that their ability to determine their own location on the map directly affected the accuracy with which targets could be designated on the map. Participants reported that the digital map/laser rangefinder system was a significant improvement over paper map methods for the accuracy and time required to plot target entities on the map. As well, targets plotted on the digital map could be easily transmitted as a report on a digital battlefield network, thereby reducing the risk of errors due to radio transfer and transcription. Overall, the GPS−based digital map integrated with the laser rangefinder greatly improved and enhanced the capabilities of infantry soldiers to perform target designation tasks.

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; Target detection; target designation; laser rangefinder; geo−referenced digital map; digital map; map and compass; target designation software; GPS