# Use of the Dismounted Soldier Simulator to Corroborate NVG Studies in a Field Setting

**Dr. Ghee Ho and Dr. John Frim**
Defence Research and Development Canada Toronto
1133 Sheppard Avenue West. P. O. Box 2000
Toronto, Ontario, M3M 3B9
CANADA

ghee.ho@drdc-rddc.gc.ca, john.frim@drdc-rddc.gc.ca

## *ABSTRACT*

*Two virtual reality (VR) laboratory studies were conducted using an immersive Dismounted Soldier Simulator (DSS) to replicate and extend a field study on Night Vision Goggle (NVG) field of view (FOV). The DSS was intended to allow for better control of confounding environmental factors identified in the field experiment. In the first VR laboratory study, experimental procedures of the field study were replicated. Soldiers 'wore' different FOV NVGs and detected randomly selected stationary targets while standing stationary at predetermined locations along the urban lane. In the second or extended laboratory study, soldiers 'wore' NVGs with either 40º, 70º, or 95º FOV and detected a series of dynamic soldier-like targets while navigating and traversing through the virtual urban village. Results from these laboratory studies seem to reveal a trend that soldiers could detect targets better while wearing NVGs with larger than 40º FOV, and performance with 70º FOV NVGs was better than with 95º FOV NVGs. Furthermore, it seemed the wider the FOV, the fewer navigation mistakes the soldiers committed.*

## 1.0 INTRODUCTION

An immersive Dismounted Soldier Simulator (DSS) was used to replicate and extend a field study on Night Vision Goggle (NVG) field of view (FOV) conducted at Ft Benning, GA, as part of the Soldier Information Requirements Technology Demonstration (SIREQ TD) project. The field experiment examined how different binocular FOV NVGs, i.e., the in-service ANVIS-9 with 40º FOV, and the prototype 70º and 95º extended FOV NVGs, can affect the target detection performance of soldiers in an urban lane target environment.

In that field study, 16 regular force infantry soldiers stood at 12 pre-determined viewing points set along an urban lane in the Fort Benning, Mckenna MOUT site, and were told to detect a randomly selected set of 8 out of 24 possible fully visible and 8 out of 24 possible semi-occluded stationary Carswell targets. In a repeated measures design, each soldier went through the trial procedure three times, once with each NVG type. During each trial the participant was led to the pre-determined viewing points and instructed to look (down) at his boots. A target was then raised (behind windows, at doorways, on rooftops, in open fields, etc.), and the participant was instructed to raise his head and begin looking for the target in the 180° arc to his front. At the same time, the experimenter began timing using a stop watch. Timing stopped as soon as the participant indicated that the target had been located; the experimenter then confirmed that the participant had located the

Ho, G.; Frim, J. (2006) Use of the Dismounted Soldier Simulator to Corroborate NVG Studies in a Field Setting. In *Virtual Media for Military Applications* (pp. 24-1 – 24-8). Meeting Proceedings RTO-MP-HFM-136, Paper 24. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

correct target. This procedure was repeated until all 16 targets were presented. The collected detection time data were analyzed using a repeated measures ANOVA procedure. The results indicated no significant differences in mean target detection time when using NVGs with 40°, 70°, and 95° FOV.

This lack of differences might be due to the fact that during the field study there was little-to-no cloud cover and a bright moon. Because of these conditions, the illumination and saliency of targets placed in various windows and doorways on both sides of the streets of the village varied with time as the moon traversed the sky over the duration of each night's testing. As a result, the saliency of the targets kept changing as the cloud condition and moon position changed, potentially introducing a significant amount of noise into the data. In order to better control for the confounding factors identified in the field study, we repeated the study in the VR laboratory using the DSS and a digital model of Fort Benning.

## 2.0 DISMOUNTED SOLDIER SIMULATOR

The DSS is an immersive simulator that uses a head-mounted display to immerse the participants in a virtual 3D environment that replicates the Fort Benning McKenna MOUT site urban lane target environment and simulates field operational conditions experienced by the dismounted soldier (e.g., night, urban lane, night vision). Six-degrees-of-freedom position sensors provide position and orientation tracking for the subject's head, torso, and weapon. Participants view the virtual environment (VE) through a position-tracked helmet mounted display (HMD). Target variables such as appearance, location, duration, and sequence can be manipulated and controlled by the experimenter with greater consistency than in the real world. Participants stand inside a safety frame while wearing a harness that houses the VR equipment cabling. Figure 1 depicts the DSS system.

**Figure 1: The Dismounted Soldier Simulator with Helmet Mounted Display, Weapon, Position Tracking Sensors, and Control Computer.**

Through the HMD, the DSS simulates viewing conditions experienced when using NVGs. A configurable screen mask provides the equivalent viewing angles of the NVGs used in the field study (40°, 70° and 95°). In addition, the scenes are coloured green with visual interference added to create realistic NVG images, similar to when looking through a binocular NVG with different FOVs.

## 3.0 DSS STUDY 1: REPLICA VR STUDY

A VR study was conducted to replicate the field experiment, but with better control of the confounding environmental factors present in the field. The environmental conditions were set to replicate a clear night sky with no moon movement, and NVG effects were set at a low noise condition as defined by the generic DSS imagery control system. Unlike the field experiment the only difference between the NVG conditions was FOV; the environmental variables remained constant across all three conditions. The aim of the laboratory study was to examine the effects of field of view of night vision goggles on target detection in a virtual urban lane target environment.

### 3.1 Method

Sixteen reserve infantry soldiers participated in this study. Each participant went through a training phase and a test phase. During the training phase the participants were trained on DSS weapon use, movement controls, target recognition, and the target detection process in the virtual urban lane environment. This training was conducted without FOV restriction in the HMD. Once immersed in the virtual urban lane the participant was 'transported' to various training viewing points. At each view point, the participant was instructed to look (down) at his virtual boots. A virtual Carswell target then appeared in similar locations to the field study and the participant was instructed to raise his head and begin looking for the target in the VE. At the same time, the experimenter began timing using the DSS. Essentially, this target presentation procedure replicated those used in the field study.

The participant then began to scan the virtual urban lane environment for the target. He indicated when the target was detected by pulling the trigger on the DSS hardware C7 rifle, at which point the DSS computer automatically stopped the timing. Each subject repeated the above training procedure until 10 consecutive targets were successfully detected. This ensured that all participants had attained a common basic level of proficiency in the target detection task and an ability to work the controls on the DSS. The viewing points and targets used for training were different from those used during the actual testing phase.

In the testing phase the DSS was programmed to replicate the Fort Benning Urban Lane field trial, with the same 48 Carswell targets situated in positions corresponding exactly to the actual field trial setting, and 12 viewing points corresponding to the actual locations used in the field trial. Just like the field study, for each trial, 16 targets were randomly selected from the repertoire of 48 targets.

Once immersed, the participant was 'transported' to various pre-determined viewing points where he went through the same target presentation procedures used in the training session. The DSS automatically tracked and recorded timing, position, and directional data for future analysis. The target detection time, defined as the time between the head raise command and firing the rifle, was recorded by the DSS computer. As in the field trial, this procedure was repeated from a variety of viewing points until all 16 targets were presented.

Each participant participated in 3 such trials with the 3 different FOVs, i.e., 40º, 70º, and 90º. The order of administration was counterbalanced to control for possible sequence effects.

# 4.0 DSS STUDY 2: EXTENDED VR STUDY

A second VR study was designed and conducted using the DSS to avoid three shortcomings of the previous study: possible learning effects arising from repeatedly presenting the same stimuli (or targets) due to the repeated measures experimental design; the participant's lack of familiarity with the procedure; and the unrealistic target scenario using static viewing points and static Carswell targets.

## 4.1 Method

In the extended VR study, participants traversed through an urban town tactically looking for life-like soldier targets situated along the urban lane (behind doors, windows, roof –top, open field, running across lane, etc.), making this task more realistic and natural to the soldiers. Targets were presented in a sequential manner such that as one target was detected it disappeared and the next target appeared further down the lane. This study was conducted using an independent group experimental design whereby each subject was only given one FOV treatment level, and all subjects used a common testing scenario with the same targets being presented.

Before going through the testing phase, all participants were trained to a high level of proficiency in movement control and target detection; i.e., able to detect 10 dynamic targets while traversing through an urban lane similar in design but different from the testing lane. During training, participants were told they could be 'shot' by the enemy soldiers if they did not respond in a tactically appropriate manner. They were also 'shot' at least once during the training session to reinforce these instructions. During the testing phase participants were never 'shot' at, although instructions did not rule out the possibility; this was done to maintain a high level of vigilance in the participants during testing. These new procedures effectively eliminated all sequence and learning effects present in previous studies and increased the realism of the virtual experience for the participants.

# 5.0 RESULTS AND DISCUSSION

For the replica study, conventional parametric and non-parametric (Friedman) repeated measures ANOVA detected significant differences between mean target detection time for the three FOV NVGs for fully visible targets placed at near (10-30m) target distances. The mean target detection time for fully visible near targets using the 40° FOV NVG was significantly longer than those for the 70° and 95° FOV NVGs. The fact that the only effect found was limited to fully visible targets placed at near target distances suggests that detection time might not be an appropriate dependent variable.

The extended study seemed to confirm that detection time might not be an appropriate dependent variable, as again no significant differences were found in ANOVA using detection time. However, frequency based data analysis did yield interesting results. Firstly, Welch ANOVA **[1, 2],** which accounts for unequal variances expected in small n samples, did yield significant differences, $F(2, 8.89) = 4.83$, $p=0.038$, between the mean numbers of missed targets with 3 different FOV NVGs. Further, post-hoc pair-wise comparisons revealed groupings as presented in Table 1, indicating that the 70° FOV NVG is significantly better than 40° FOV NVG, since users of 70° FOV NVG tended to miss fewer targets than those using 40° FOV NVG.

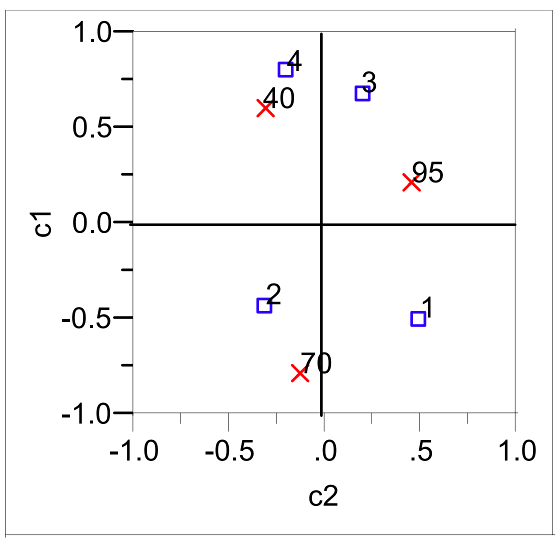
**Table 1: Post-hoc Pairwise Comparison Groupings of Number of Missed Targets in DSS Study 2**

| FOV | Groupings | Mean |
|---|---|---|
| 40° | A | 3.00 |
| 95° | A B | 2.34 |
| 70° | B | 1.67 |

This finding is further supported by the correspondence analysis plot [3, 4] depicted in Figure 2. Correspondence analysis procedures were developed to enhance the resolution of pattern structures in contingency or frequency data.

Correspondence analysis can be seen as a hybrid form of principal component analysis of rows and/or columns utilizing contingency (cross-tabulation) data instead of the usual continuous data. It represents the optimal relationship between categorical variables in a two dimensional correspondence plot.

In Figure 2, “FOV” and “number of missed targets” profiles are associated with each other if their points fall in approximately the same direction away from the origin and are located in the same proximity on the correspondence plot. The relative positions of the labels indicates that the 70° FOV NVG tends to be associated with ‘1 and 2 missed’ targets, and the 95° FOV NVG tends to be associated with ‘3 missed’ targets, whereas 40° FOV NVG tends to be associated with ‘4 missed’ targets. This means that participants who wore the 70° FOV NVG tended to miss fewer targets when compared to participants who wore the 95° and 40° FOV NVGs.




Where:

represents various levels of “FOV”

represents various levels of “No. of missed targets”

**Figure 2: Correspondence Plot of “FOV” and “Number of Missed Targets” Profiles for DSS Study 2.**

Furthermore, by analyzing the entity position tracking data collected by the DSS sensors, we are able to retrace the path taken by the subjects while traversing through the virtual lane, and hence are able to determine whether the subjects took "wrong turns" and if so how many (i.e., number of mistakes made while traversing through the pre-determined L-shaped urban lane). The number of navigation mistakes the subject made while traversing the virtual testing lane also yielded significant differences, $F(2, 9.10) = 4.59$, $p=0.042$. Further post-hoc pairwise comparison revealed groupings as presented in Table 2.

**Table 2: Post-hoc Pairwise Comparison Groupings of Number of Navigation Errors in DSS Study 2**

| FOV | Groupings | | Mean |
|---|---|---|---|
| 40° | A | | 1.17 |
| 70° | A | B | 0.83 |
| 95° | | B | 0.17 |

This finding is further supported by the correspondence plot depicted in Figure 3, which indicates that 95° FOV NVG tends to be associated with '0' navigation mistakes, 70° FOV NVG tends to be associated with '1' navigation mistake, whereas, 40° FOV NVG tends to be associated with '2' navigation mistakes. Hence, the wider the FOV of the NVG, the better it enables users to navigate.

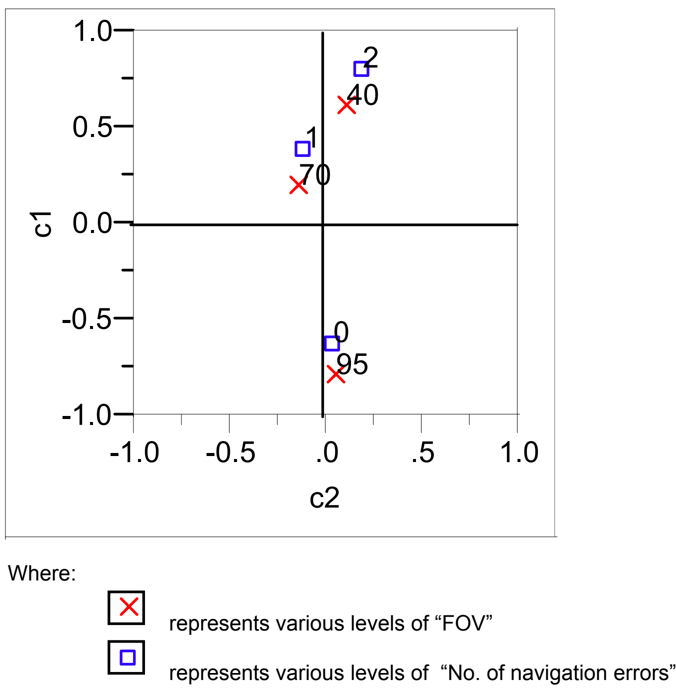



**Figure 3: Correspondence Plot of "FOV" and "Number of Navigation Errors" Profiles for DSS Study 2.**

## 6.0 CONCLUSION

Summarizing the core findings across the two studies, in general, there seems to be little or no difference in mean detection time between the three FOV NVGs; the only difference was a longer detection time with 40º FOV for fully visible targets at near distances. However, frequency analysis and correspondence analysis did uncover interesting trends in the data of the second DSS study. Participants using the 70° FOV to detect targets tended to do better than when they used the other NVGs, the 70° NVG resulting in fewer missed targets than the 40° and 95° NVGs. It is known that in human vision only the central 3-5º of the whole visual field provides high acuity vision, and outside this small central area visual acuity quickly diminishes [5, 6]. Perhaps extending the FOV of NVGs to try to match that of natural vision is not the key to developing better NVGs. Under restricted FOV, individuals will try to adapt by scanning their eyes faster, moving their head and body quickly to compensate for the lack of FOV. Therefore, the overall target detection time differences between the different FOVs may be very small. When it came to finding a target, it seemed that a 70° FOV is a good 'happy medium', providing a compromise between having to scan excessively with the eyes, and having to move the head and body quickly to compensate for the lack of FOV.

Furthermore, the wider the FOV of the NVG the better it seemed to enable users to navigate in the virtual urban environment, resulting in fewer navigation mistakes such as missing a turn or wandering off course. Unlike detecting a target, where the 'happy medium' 70° seemed to be the best FOV level, the navigation task required the maintenance of an overall mental and relational picture of the environment. Therefore, the larger the FOV, the better it seemed to allow the users to maintain and update their mental picture, and hence they are better able to know where they are in the environment, and which direction they should be travelling.

In spite of the supporting evidence in the data, the small sample size of the DSS studies suggests future studies with larger samples are needed in order to confirm these trends in the VR environment and to cross validate with another field study.

## 7.0 REFERENCES

[1] Welch B.L. (1951) On the comparison of several mean values: An alternative approach. *Biometrika*. 38:330–336.

[2] Hartung J, Argaç D, Makambi K.H. (2002) Small sample properties of tests on homogeneity in one-way ANOVA and meta-analysis. *Statist Papers*. 43:197–235.

[3] Greenacre, Michael J. (1993).*Correspondence Analysis in Practice*. London: Academic Press.

[4] Hill, M.O. (1974) Correspondence analysis: a neglected multivariate method. *Applied Statistics*, 23, 340-54.

[5] Task, H. L. (1992) Cockpit / NVG Visual Integration Issues. *AGARD Lecture Series 187: Visual Problems in Night Operations* (pp. 8-1 - 8-6). Neuilly Sur Seine, France: NATO Advisory Group for Aerospace Research & Development. (NTIS No. AGARD-LS-187)

[6] Wells, M. J., Venturino, M., and Osgood, R. K. (1989) Effect of field of view size on performance at a simple simulated air-to-air mission," in *Helmet-mounted displays, Proceedings of SPIE 1116*, March 1989.