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Virtual Environment Study of Sensor Mix Effects on Ground Soldiers' Situational Awareness

by Daniel D. Turner and Christian B. Carstens

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Daniel D. Turner and Christian B. Carstens
Human Research and Engineering Directorate, ARL

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14. ABSTRACT
The Fort Benning (Georgia) Field Element of the Human Research and Engineering Directorate of the U.S. Army Research Laboratory conducted an experiment in conjunction with the Communications and Electronics Command's Research, Development, and Engineering Center, Night Vision Electronic Sensor Division, to investigate the effects of different sensor mixes on the situational awareness (SA) of dismounted Soldiers. The results from this study will be used to document the level of sensors needed for Soldiers to maintain SA with information systems such as the Smart Sensor Web in military operations in urban terrain environments. The experiment was conducted in the Soldier Battle Lab's squad synthetic environment, a virtual environment that allows the squad to participate in force-on-force exercises. The four squads that participated in the experiment conducted infantry operations using vignettes that were prepared to include as many situations as possible that are typically encountered during infantry operations. At selected points in the vignette, the Soldiers were administered SA critical information knowledge assessment questionnaires to determine the level of SA achieved with each of the four sensor mix options. These mixes were

- Mix 1- Distributed cueing sensors in key locations around the village (acoustic, seismic, magnetic sensors that can discriminate by type, person, vehicle).
- Mix 2- Mix 1 sensors plus one hovering/perching unmanned aerial vehicle (UAV) with fixed infrared camera sensor. Mix 3– Mix 1 and 2 sensors plus fixed imagers in key locations inside the village.Mix 4- Mix 1, 2, and 3 sensors plus advanced cueing sensors with automated target detection and classification, autonomous imagers, and one additional hovering/perching UAV with fixed infrared camera sensor.The results indicated that the addition of fixed imagers in key locations inside the village significantly increases the SA of the individuals in the infantry squad.

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ground sensors; MOUT; situational awareness

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Executive Summary

The Fort Benning Field Element of the Human Research and Engineering Directorate of the U.S. Army Research Laboratory (ARL) conducted an experiment to investigate the effects of sensor mix on the situational awareness (SA) of an infantry squad in military operations in urban terrain (MOUT) scenarios. The other squads in the platoon and adjoining units were "played" with simulated traffic flow. This allowed the evaluated squad to conduct valid missions as part of a larger (platoon/company) unit. The units conducted both an offensive (occupy attack position and attack) and a defensive (plan for counter attack and defense) operation. Previously, Redden (2002) validated the use of the squad synthetic environment and found that it provided results similar to those obtained in a live environment.

The Communications and Electronics Command's Research, Development, and Engineering Center, Night Vision Electronic Sensor Division, provided the four sensor mix levels for the experiment. The SA critical information knowledge assessment questionnaires were constructed on the basis of vignettes to document the SA achieved by the infantry Soldiers after each phase of the two operations with each sensor mix. These mixes were

- Mix 1 - Distributed cueing sensors in key locations around the village (acoustic, seismic, magnetic sensors that can discriminate by type, person, vehicle).
- Mix 2 - Mix 1 sensors plus one hovering/perching unmanned aerial vehicle (UAV) with fixed infrared camera sensor.
- Mix 3 – Mix 1 and 2 sensors plus fixed imagers in key locations inside the village.
- Mix 4 - Mix 1, 2, and 3 sensors plus advanced cueing sensors with automated target detection and classification, autonomous imagers, and one additional hovering/perching UAV with fixed infrared camera sensor.

Findings indicate that the type of sensor mix had an effect on the SA of an infantry squad during offensive and defensive actions in a MOUT battle. Overall, the addition of fixed sensors inside the village (Mix 3) contributed the greatest increase to the SA of the infantry soldiers.

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1. Introduction

1.1 Purpose

The purpose of the study was to investigate the effects of different levels of sensor mix on the situational awareness (SA) of the infantry Soldier and on the infantry Soldier as part of the infantry squad. The results from this study will be used to document design guidelines for the smart sensor web (SSW) information display. Two previous studies acted as pilot tests for the methodology used in the present study.

1.2 Background

The types and locations of sensors on the battlefield, which are required to provide the ground Soldier with sufficient information to be situationally aware in military operations on urbanized terrain (MOUT), have not been determined to date. Previous experiments conducted by the SSW program have indicated that the use of sensors on the MOUT battlefield is instrumental to the success of operations. However, the questions of, "What types of sensors are needed?" and "Where should they be placed on the battlefield?" have not been addressed. The dismounted Soldier is primarily a fighter, and it is critical that the sources of this information not interfere with but enhance his infantry tasks. It is important to evaluate the degree to which the Soldier's information system provides an increase in SA and helps him think and act quickly. The Program Manager (PM) of the SSW program recognized this importance and addressed it by commissioning the U.S. Army Infantry School (Fort Benning, Georgia), a field element of the U.S. Army Research Laboratory's (ARL) Human Research and Engineering Directorate, in support of the Night Vision and Electronic Sensors Directorate Communication Electronics Command to perform this study.

1.2.1 Virtual Environment Study of Mission-Based Critical Information Requirements

The Virtual Environment study (Redden, 2002) was performed with the squad synthetic environment (SSE) (see paragraph 2.2.1 for a description) housed at Fort Benning. The study was executed by the ARL's Fort Benning Field Element in conjunction with the Simulations and Modeling Division of the Soldier Battle Lab (SBL). Results from this study documented the critical information requirements (CIRs) for infantry Soldiers in platoon leader, squad leader, fire team leader, and squad member positions.

This investigation included a validation study to ensure that the data obtained with the simulator would be consistent with data obtained during live operations. During the validation study, Soldiers conducted a vignette that had previously been conducted in a live exercise at the McKenna, Georgia MOUT site (see figure 1) by three ranger platoons. At the conclusion of the vignette (both live and simulation), Soldiers were administered a CIR questionnaire that asked them to rate the importance of specific information requirements in the vignette. The importance ratings of the information to the Soldiers in the simulation vignettes were then compared to the importance ratings of the Soldiers who conducted the live vignettes to determine whether the information requirements in the simulator were similar to the cognitive requirements in the live exercises. The results obtained with the SSE were very similar to those obtained in a live environment.

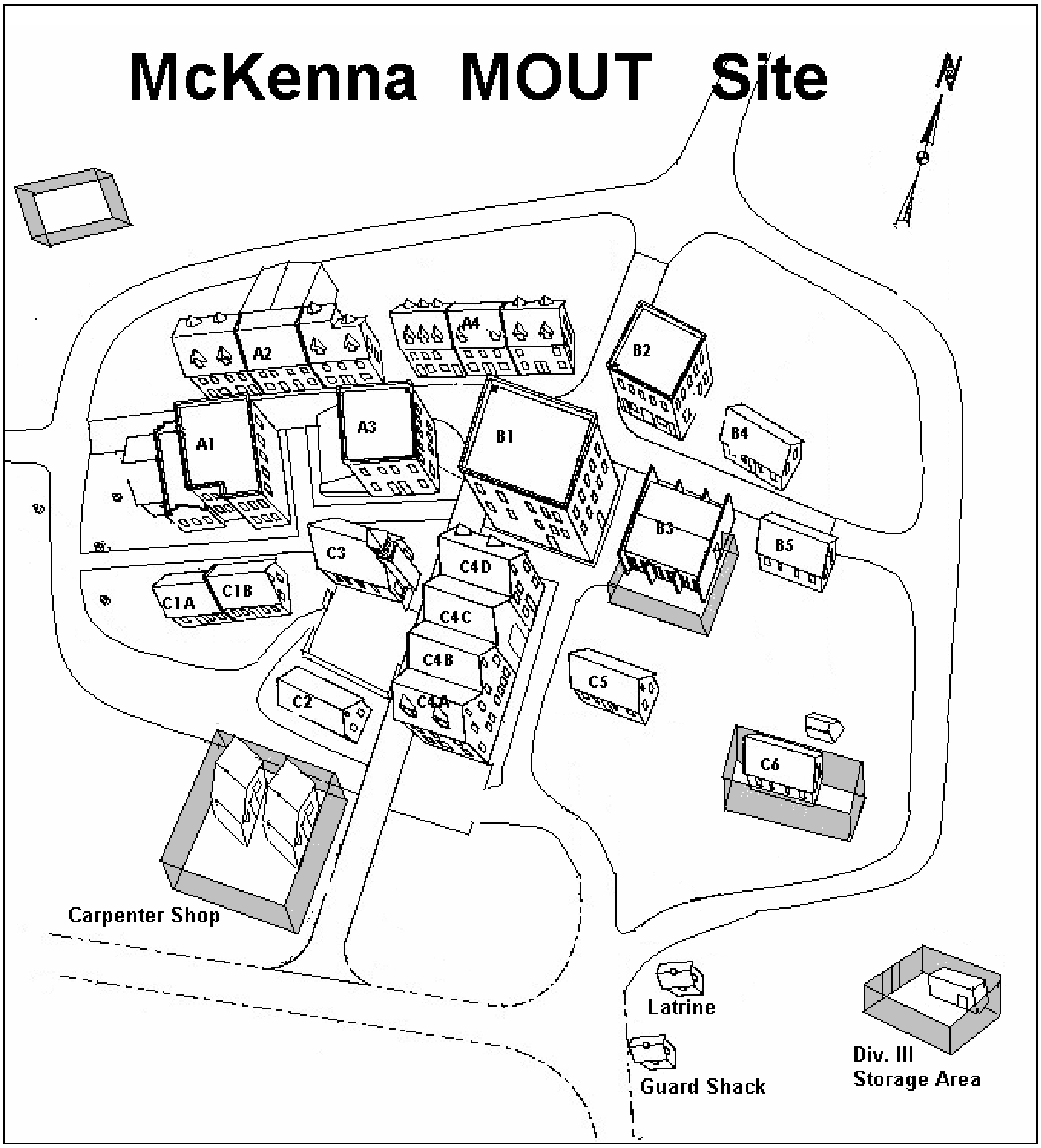

Figure 1. McKenna MOUT site.

1.2.2 Smart Sensor Web Field Experiment

The SSW study (Office of the Deputy Under Secretary, 2002) was conducted at the McKenna MOUT facility and used live opposing force (OpFor) and civilians on the battlefield (COB) in vignettes. The SA assessment center methodology and the critical information knowledge assessment (CIKA) questionnaires used in this experiment were able to discriminate between baseline, technology level 1 (mid-term, technology expected to be available in 3 to 5 years), and technology level 2 (long-term, technology expected to be available in 5+ years) conditions, demonstrating the potential of the SSW to increase the SA of the infantry squad.

2. Method

2.1 Participants

Four Canadian sections from the First Canadian Infantry Regiment, consisting of ten infantry Soldiers per section, were used for this study. Each Canadian section had an experienced squad leader and a second in command (2IC), which is similar to the U.S. infantry fire team leader.

2.2 Apparatus

2.2.1 Squad Synthetic Environment

To support the operational context of this experiment, the virtual test bed at the SBL simulation center was used to assess SA and the key technical elements associated with determining which level was best for each phase of the MOUT operation.

The simulator configuration used for this study consisted of a command and control center (see figure 2) (two control personal computers), nine interactive Soldier visualization stations (figure 3), and a maximum of eight interactive stations that controlled the OpFor and COBs. Pleban, Eakin, Salter, and Matthews (2001) provide additional information about the configuration of the SSE simulator.

Additionally, the system included a dismounted infantry simulated automated forces (DISAF) simulator. This system portrays a two-dimensional icon for different types of Soldiers on the battlefield and is used to show movement of OpFor, COBs, and friendly forces other than the unit in the interactive Soldier visualization stations. This information was sent to the Soldiers via a forearm-mounted display manufactured by Xybernaut Corporation (see figure 4) and was also available for call by the Soldiers.

Figure 2. Squad synthetic environment simulator command and control.

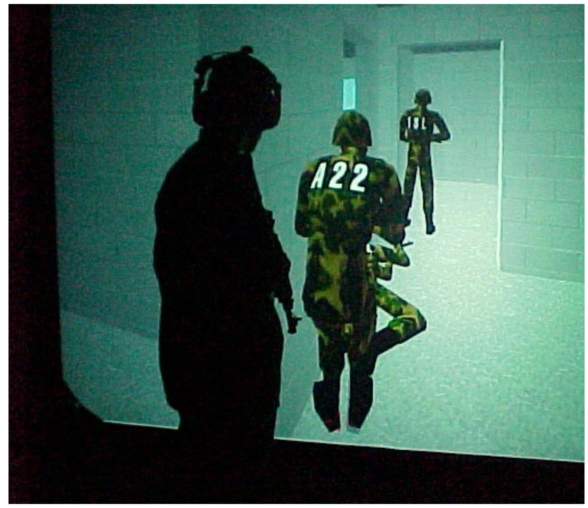

Figure 3. Squad synthetic environment simulator interactive Soldier.

Figure 4. Soldier using Xybernaut.

2.2.2 Vignettes

Vignettes were developed for the two mission-based scenarios selected for this study (attack and clearing of a building, and defending a MOUT objective). The vignettes were tailored to meet virtual environment requirements. Four scripts were written for each vignette to control the movement and action of the OpFor and COBs. An attempt was made to vary the scripts and the vignettes so that the Soldiers would be confronted with as many conditions as possible during the experiment. Table 1 provides a definition of the vignette tactics and scripts used for this experiment.

Table 1. Definition of vignette tactics and scripts.

Vignette	Tactics	Script 1	Script 2	Script 3	Script 4
A	Squad attacks and clears a free-standing building that consists of three rooms and a bell tower. Squad attacks across an open danger area.	3 COBs on Objective. 2 OpFor engage and try to escape. 9 OpFor counter attack from west.	2 COBs on objective. 5 OpFor on objective. 4 OpFor counter attack from A1, 5 OpFor counter attack from A2/A3.	3 COBs on objective. 4 OpFor on objective. 15 OpFor counter attack from the west.	3 COBs on objective. 1 OpFor in tower 3 OpFor on objective, attempt to escape to A1. 18 OpFor counter attack from west.
B	Squad conducts a defense mission preparing for counter-attack. Squad occupies two buildings or the second floor of a multi-floor multi–apartment building and observes OpFor activity on the northern and eastern sides of McKenna MOUT site.	4 COB in courtyard of jail, 2 COB walking from cemetery. 3 OpFor track vehicles northeast. 8 OpFor attack from northeast.	5 COBs dead on battlefield. 2 COBs under guard north. 2 OpFor dead on battlefield. 16 OpFor mount first attack, followed by second attack of 15 OpFor.	6 COBs dead on battlefield. 3 COBs north. 23 OpFor attack from north and northeast.	5 COBs and dead on battlefield. 2 COBs north. 2 OpFor dead on battlefield. 12 OpFor first attack from north. 3 OpFor vehicles and 18 OpFor mount surprise counter attack from southeast.

The vignettes were constructed to enhance realism and challenge the Soldiers with an array of operationally relevant experiences. Two primary vignettes (offensive and defensive vignettes) were developed and are described in table 1 (vignettes A and B). The vignettes describe a general tactical theme, and the scripts comprise controlled variations around each vignette theme. For example, in vignette A, the squad attacks and clears a free-standing building that consists of three rooms and a bell tower. In addition, the squad attacks across an open danger area. Each of the four scripts to this vignette has this general theme, with similar levels of COB and OpFor presenting comparable levels of situation demand, in order to allow comparison among the vignettes.

2.2.3 McKenna MOUT Site and Xybernaut

McKenna MOUT site was used as the terrain for the development of the vignettes and scripts (figure 1). The Soldiers received their initial MOUT training at McKenna. All activity in the SSE was based on data and configurations from McKenna MOUT site.

The wrist-worn Xybernaut was used as a surrogate instrument for receiving data and information from the sensors. All soldiers in the SSE wore the Xybernaut during the exercise. With the Xybernaut, information could be provided to the squad members or used as needed by each member of the squad.

2.3 Procedures

2.3.1 Training

Personnel from SBL gave the experiment Soldiers training in the SSE, the Xybernaut, and MOUT tactics at McKenna MOUT site. Each squad was given time to learn operation of the simulator; then they were given an opportunity to conduct an operation using a practice vignette.

2.3.2 Demographics

Upon arrival, the experiment Soldiers were given a demographic questionnaire (see appendix A for results). All the Soldiers were assigned a roster number.

2.3.3 Questionnaires

The CIKA questionnaires were administered during pre-planned pauses. Each Soldier completed the questionnaires independently. These pre-planned pauses were

- Occupy the Attack Position. The stage of an offensive operation when the Soldiers occupied the last covered and concealed position and were able to finalize their attack plan, based on the unfolding battle of the remaining units (portrayed by "white cell[1]" traffic).
- Attack Position. The stage of an offensive operation when the Soldiers conducted a squad-size attack on an objective, including the completion of that mission.
- Planning for the Counter Attack. The stage of an operation when the unit changes from offensive to defensive operations. The unit is in a hostile environment and the OpFor is maneuvering into position to mount a counter attack against the experimental force (ExFor).
- Defense. The stage of an operation when the unit is in a defensive posture and defending an assigned piece of real estate.

The data collected during each stage of the battle were analyzed and tabulated by the sensor mixes and by a combination of all the stages into an overall score.

During all phases, data were available to the Soldiers from the particular sensor mix used. The Soldiers had the option of "pulling" data (i.e., using data about specific locations or actions), or in some cases the data were "pushed to" them (i.e., data assumed to be critical for the mission provided by the platoon leader). The platoon leader determined what data should be sent (pushed down) to the squad, and he maintained the same level of information for all squads.

[1]A white cell consists of personnel who role played higher headquarters in the simulation.

2.4 Experimental Design

Four squads participated in the study. Each squad completed four alternate scripts for each vignette, as shown in table 2.

Table 2. Matrix for SSW sensor mix experiment.

Day	First Squad	Second Squad	Third Squad	Fourth Squad
1	Vignette A, Mix 1	Vignette A, Mix 2	Vignette A, Mix 3	Vignette A, Mix 4
	Vignette B, Mix 2	Vignette B, Mix 3	Vignette B, Mix 4	Vignette B, Mix 1
2	Vignette A, Mix 2	Vignette A, Mix 3	Vignette A, Mix 4	Vignette A, Mix 1
	Vignette B, Mix 3	Vignette B, Mix 4	Vignette B, Mix 1	Vignette B, Mix 2
3	Vignette A, Mix 3	Vignette A, Mix 4	Vignette A, Mix 1	Vignette A, Mix 2
	Vignette B, Mix 4	Vignette B, Mix 1	Vignette B, Mix 2	Vignette B, Mix 3
4	Vignette A, Mix 4	Vignette A, Mix 1	Vignette A, Mix 2	Vignette A, Mix 3
	Vignette B, Mix 1	Vignette B, Mix 2	Vignette B, Mix 3	Vignette B, Mix 4

*Sensor Mix Conditions:

- Mix 1- Distributed cueing sensors in key locations around the village (acoustic, seismic, magnetic sensors that can discriminate by type, person, vehicle).
- Mix 2- Mix 1 sensors plus one hovering/perching unmanned aerial vehicle (UAV) with fixed infrared camera sensor.
- Mix 3- Mix 1 and 2 sensors plus fixed imagers in key locations inside the village.
- Mix 4- Mix 1, 2, and 3 sensors plus advanced cueing sensors with automated target detection and classification, autonomous imagers, and one hovering/perching UAV with fixed infrared camera sensor.

The examination of the individual and squad SA was conducted in an operational context with a Canadian section as part of a coordinated infantry battalion operation on a MOUT mission. The platoon, company, and battalion players were simulated by the white cell concept for information flow. The Soldiers were presented with virtual OpFor and COB situations. The pre-programmed OpFor and COBs were used in each alternative as identified in table 1 and to show the results of combat actions of the first and third squads of the infantry platoon. Additionally, the pre-programmed friendlies on each flank were shown on the DISAF simulator.

2.4.1 Independent Variable

The independent variable was the mix of sensory information (mix 1 through 4) provided to the Soldiers.

2.4.2 Dependent Variable

The dependent variable was proportion of correct responses to the SA questions.

2.5 Limitations

The synthetic environment does not create those human elements of fear, urgency, fatigue, and battle confusion to the same extent as a live troop environment. The SSE cannot easily simulate many important battlefield features such as accurate information about the disposition of COBs (i.e., interaction with the OpFor), identification of automatic weapons, and locations of leadership personnel.

Placement of the different sensor suites was not optimum during this experiment. The decision about placement and reaction time was completed without coordination of the vignette writer, so actual location of activities may not have been completely recorded by the system. The placement of the sensors was maintained throughout the experiment to ensure consistency. However, this is a very realistic condition. In the real world, placement of sensors would probably not be optimal and one could expect some gaps in the sensor systems. The Canadian platoon leader handled the maneuvering of sensors with guidance from the experiment staff.

3. Results

3.1 Training

The Soldiers stated that the pre-experiment training using the Xybernaut, MOUT tactics, techniques, and procedures (TTPs) at McKenna MOUT site and the SSE training were adequate and prepared them to conduct the simulated combat missions for this experiment.

3.2 Demographics

The four Canadian sections were at full strength (a total of 40 Soldiers) and had an average age of 25.25 years. The Soldiers had an average of 12.68 years of education and 5 years 5 months of military service with 2 years 5 months in their current positions. All the Soldiers were qualified in an infantry specialty. Average military training and instruction received in infantry operations (including classroom training and field exercises) was 1 year 3 months. Their self-evaluation of individual knowledge, skills, and abilities was slightly below average with a self-assessment of 3.01 on a 7-point scale. (Detailed results are given in appendix A.)

3.3 SA Trials

The results of all the SA trials are presented in appendix B. In this experiment, mix 1 was always conducted with script 1, mix 2 with script 2, mix 3 with script 3, and mix 4 with script 4. Although it would have been preferable to randomize the sensor mix conditions within the four scripts, factors beyond our control precluded this from happening. However, pilot tests of the four scripts conducted before this experiment indicated that the scripts were essentially of equal difficulty since there were no significant differences among the scripts in terms of mean SA questions answered correctly.

3.3.1 Occupy the Attack Position

Table 3 shows the mean SA values for the four mixes in the "occupy the attack position" phase. A repeated measures analysis of variance (ANOVA) was used to compare the mean percentages of correct responses on the SA questions. (Because there were different numbers of SA questions for the different vignettes, mean proportions of correct responding are reported.) The difference among the means was statistically significant: $F(3,117) = 4.26$, $p = .007$.

Table 3. Means and SDs by mix – occupy-the-attack position.

	n	Mean	SD
Mix 1	40	.17	.18
Mix 2	40	.20	.20
Mix 3	40	.30	.22
Mix 4	40	.29	.24

All ensuing comparisons were done with Holm's sequential Bonferroni procedure to control for family-wise error rates. For this analysis, and all subsequent analyses, pairwise comparisons are limited to each mix condition compared with its next richer mix condition. The pairwise comparisons were conducted in this way in an attempt to identify the specific points at which the richness of the mix enhanced SA. As indicated in table 4, the mean for mix 3 was significantly higher than the mean for mix 2.

Table 4. Ensuing comparisons – occupy-the-attack position.

Comparison	t	df	Required alpha	Significance
Mix 1 - 2	.45	39	.025	.653
Mix 2 – 3	2.81	39	.017	.008*
Mix 3 - 4	.29	39	.05	.772

*Significant, $p < .05$, 2-tailed

During the occupy-the-attack position phase of the offensive operation, the Soldiers were in the last covered and concealed position before launching their attack. The other squads (simulated) in the platoon were conducting their portions of the operation during this phase. The Holm's sequential Bonferroni revealed a significant improvement in the squad's SA when the fixed imagers were used in key locations inside the village. There were no significant differences in the other paired comparisons. The squad had the time to call and observe data and use the addition of fixed imagers from inside the village to increase their SA. Therefore, they were more aware of what was going on in and around their objective.

3.3.2 Post-Attack Phase

The means for the four mix conditions are shown in table 5. The differences among the means were statistically significant: $F(3,117) = 11.34$, $p < .001$.

Table 5. Means and SDs by mix - post-attack phase.

	n	Mean	SD
Mix 1	40	.18	.17
Mix 2	40	.09	.11
Mix 3	40	.28	.17
Mix 4	40	.22	.17

Ensuing comparisons were conducted with Holm's Bonferroni control procedure, as shown in table 6. The mean for mix 2 was significantly lower than the means for mix 1 and mix 3.

Table 6. Ensuing comparisons - post-attack phase.

Comparison	t	df	Required alpha	Significance
Mix 1-2	2.81	39	.025	.008*
Mix 2-3	6.23	39	.017	< .001*
Mix 3-4	1.86	39	.05	.070

*Significant, $p < .05$, 2-tailed

The data for the post-attack phase were collected after the squad secured the objective. The squad members had been busy conducting the actual attack and may have not have had as much of an opportunity to observe the data from the different sensor suites as they did in the more static posture of occupy the attack position.

The results from mix 2 appear to be a function of the script used for that mix. During mix 2, there was a substantial reduction, relative to mix 1, in the proportion of Soldiers correctly answering questions that addressed the location, size, movement, and intent of the OpFor outside the village. In mix 1, the sensors outside the village adequately picked up the activity of the OpFor outside the MOUT site. In the mix 2 script, there were no OpFor outside the village. The Soldiers did not appear to trust the sensors and assumed that there were OpFor outside the MOUT site. Therefore, they answered the questions pertaining to the OpFor incorrectly. All questions that did not address the OpFor outside the village were answered with essentially the same level of correctness with both mix 1 and mix 2. Thus, mix 1 and mix 2 were probably essentially equal if system trust were removed from the equation and mix 2 did not contribute to the SA over mix 1.

Mix 1 sensors around the outer edges of the MOUT site were adequate to keep the Soldiers aware of the enemy situation outside the village. The squad leader and squad personnel were able to detect counter attack activity of the OpFor. The sensors provided by mixes 2, 3, and 4 did not appear to contribute to this phase of the battle because the operational tempo was so fast and Soldiers had very little time to watch their screens.

3.3.3 Planning the Counter-Attack

The SA means and standard deviations are shown in table 7. The differences among the means were not statistically significant: F (3,117) = 1.80, *p* = .150.

Table 7. Means and SDs - planning the counter-attack

	n	Mean	SD
Mix 1	40	.31	.13
Mix 2	40	.36	.21
Mix 3	40	.37	.16
Mix 4	40	.35	.18

During the planning for counter-attack phase, the Soldiers once again had significant time to prepare and observe data from the different sensor suites. However, because of the placement of the OpFor during this phase, mix 1 (distributed cueing sensors in key locations around the village) sensors may have been placed to give sufficient information, and the addition of sensor suites (mixes 2 through 4) would have only confirmed the data from mix 1. The counter-attack by the OpFor was staged on the periphery of the MOUT site and in the northern-most buildings. The placement of the sensors in mix 1 was on the perimeter of the MOUT site and may have contributed sufficient information of the OpFor moving into the counter-attack positions during this phase. The placement of these sensors would have given the ExFor Soldiers adequate information about direction and timing of the counter-attack as well as the size of the counter-attack force.

3.3.4 Defense Phase

Table 8 shows the means for the defense phase. The differences among the means were statistically significant: F (3,117) = 5.45, *p* = .002.

Table 8. Means and SDs - defense phase.

	n	Mean	SD
Mix 1	40	.22	.19
Mix 2	40	.33	.25
Mix 3	40	.31	.19
Mix 4	40	.39	.15

The ensuing comparisons are shown in table 9. The difference in SA between mix 2 and mix 1 approached statistical significance.

Table 9. Ensuing comparisons - defense phase.

Comparison	t	df	Required alpha	Significance
Mix 1 – 2	2.47	39	.017	.018
Mix 2 - 3	0.57	39	.05	.573
Mix 3 - 4	2.10	39	.025	.042

During the defense Phase, the squad was defending a specific piece of real estate in conjunction with the remaining two squads (simulated) of the platoon. During this phase, the activity level would have been very high as in the offensive attack phase, but the squad would have been static in the defense and moving during the attack phase. The data revealed a marginally significant increase in SA with mix 2 over mix 1. The addition of the hovering/perching UAV with fixed infrared camera sensor contributed to this difference. There was also a marginally significant increase in SA with mix 4 over mix 3. The addition of advanced cueing sensors with automated target detection and classification, autonomous imagers, and two hovering/perching UAVs played a role in this difference. This is partly attributable to the Soldiers' use of the higher resolution sensor suites in mix 4 and their ability in a static defense position to retrieve data from them. There was no significant difference between mix 3 and mix 2.

3.3.5 Overall

In order to evaluate the overall influence of sensor mix on SA, we summed the Soldiers' responses across the four phases of the experiment. Table 10 shows the mean results of all questions from the occupy attack phase, the attack phase, the planning for counter-attack phase, and the defense phase by alternative. The differences among the means were statistically significant: $F(3, 117) = 11.59$, $p < .001$.

Table 10. Means and SDs – overall.

	n	Mean	SD
Mix 1	40	.22	.11
Mix 2	40	.24	.10
Mix 3	40	.32	.11
Mix 4	40	.30	.11

Ensuing comparisons (table 11) indicate that the mean for mix 3 was significantly higher than the mean for mix 2.

Table 11. Ensuing comparisons – overall.

Comparison	t	df	Required alpha	Significance
Mix 1 – 2	1.18	39	.025	.246
Mix 2 - 3	3.58	39	.017	.001*
Mix 3 - 4	.71	39	.05	.482

4. Discussion

The data from all phases by mix, except the planning the counter-attack phase, revealed that a significant increase in SA comes with the addition of the fixed imagers in key locations inside the village (mix 3). The hovering/perching UAV is not significantly better than distributed cueing sensors in key locations around the village (mix 1), and the addition of advanced cueing sensors and an additional hovering perching UAV (mix 4) is not significantly better than mix 3. The addition of the fixed imagers in key locations inside the village and inside the buildings clearly adds the most clarity in this experiment. Quite often, the Soldiers used the mix 3 sensor suite to confirm suspected OpFor activities. This happened even more frequently when the ExFor had the opportunity to observe their screens during the preparation phases (occupy the attack position and plan for counter-attack). Personnel from ARL's Human Research and Engineering Directorate observed the squads using the mix 3 capabilities in the attack and defense phases to confirm activity in and around their objective or defensive position.

The flexibility of the hovering/perching sensors, when used by the squad, contributed to enhanced SA, but only if the Soldiers were able to place these moving sensors quickly enough to be of use. Too often during the conduct of attack or defense, there was insufficient time to place these types of sensors in key locations. If the hovering/perching UAVs are not in the right place at the right time, they are less useful. The addition of the mix 4 sensor suite did not often increase the SA of the squad except during the defense. The additional sensors of the mix 4 option may have given the Soldiers better insights when used in this relative fixed position where a lot of activity was directed at the squad. The slower reaction time of these sensors could better be used in this type of vignette. Additionally, we may have approached the point of "how much is enough" (diminishing returns) once the fixed imagers in key locations inside the village were added.

The biggest concern continues to be the correct use of the available sensor data. Quite often, the infantry Soldiers did not have the time to call the images required in this experiment. However, if the data are available or if critical data are provided to the Soldiers, they will be more likely to use available information.

As witnessed in the post-attack phase, there are indications that Soldier trust in the capabilities of the sensors can play a significant role their SA. In this case, they did not trust the apparent absence of OpFor outside the village. Their error was "it is better to assume the worst," because the machines may not detect OpFor outside the MOUT site. In summary, mix 3 contributed the most to the SA of the Soldiers.

The percentages of correct SA responses tended to be rather low in this experiment. For overall SA, even the optimal mix of sensory information yielded only a third of the SA questions answered correctly. This may indicate that the questions used in this study were excessively difficult.

5. References

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Appendix A. Demographic Questionnaire Results

SAMPLE SIZE = 40

DUTY POSITION FOR THIS EXPERIMENT	**AGE**
Squad Leaders – 4	Mean = 25.25 years
Infantry Soldiers – 36	(Range 19-36 years)

1. Handedness: 32 Right 8 Left

2. Height: Mean = 70.50 inches (Range 64 to 75 inches)
3. Weight: Mean = 183.45 pounds (Range 135 to 250 pounds)
4. Vision:

   a. Do you wear glasses when performing military duties?

   9 Yes 31 No

   b. Do you wear contact lenses when performing military duties?

   1 Yes 39 No

   c. Is your vision in each eye 20/20 or correctable to 20/20?

   36 Yes 4 No

5. Education: Mean = 12.68 years

6. Current MOS / Months (Mean) in Current MOS

Current MOS	Months (Mean) in Current MOS
031 Canadian Infantry	34.28 months

7. Months (Mean) in current job = 19 months
8. Months (Mean) of experience in Infantry-related MOS = 48 months
9. Months (Mean) of military service = 61 months
10. Months (Mean) in these leadership positions:

    a. Fire Team Leader = 13 months
    b. Squad Leader = 7 month

11. Months (Mean) of military training/instruction received in light infantry operations:

    a. Classroom training at Infantry school = 12 months

    b. Field exercises (i.e., NTC, JOTC, CRTC, JRTC, = 17 months MOUT training)

12. Months (Mean) of military training/instruction received in the following areas:

a. Land navigation (map reading, use of GPS data, = 19 months following planned route)

b. Route planning = 13 month
c. Communications = 11 months

15. Self rating of Knowledge, Skills, and Abilities (KSA) related to Infantry duties:

1 Poor	2 Below average	3 Average	4 Above average	5 Outstanding

MEAN RESPONSE	
Knowledge of infantry TTPs.	3.50
Knowledge of computers.	2.85
Knowledge of electronics.	2.58
Knowledge of mechanics and maintenance procedures for weapon systems and equipment used.	3.25
Knowledge of map reading and orientation in field setting.	3.60
Knowledge of land navigation.	3.58
Knowledge of reconnaissance, surveillance, and target acquisition procedures.	3.33
Knowledge relating to communications equipment and communications procedures.	3.28
Marksmanship skills.	3.53
Map reading skills.	3.65
Land navigation skills.	3.68
Computer skills (keyboards, mouse, track balls, navigating in and out of menus, etc.).	3.10
Communication skills (ability to use communications equipment and face-to-face communications to enhance mission accomplishment).	3.28
Leadership skills	3.33

16. Months (Mean) of military deployment for peacekeeping, peace enforcement, stability operations of combat = 5.73 months:

Croatia
Bosnia
Kosovo
Herzegovina
Somalia
Cyprus

Appendix B. Situational Awareness Questionnaire Results

Occupy-the-Attack Position Means:

Question	Mix			
	1	2	3	4
What is the status of COBs on Objective 2?	.10	.15	.18	.13
How many OpFor are on Objective 3?	.08	.13	.33	.33
Where, if any, are the OpFor located on Objective 3?	.03	.23	.53	.28
How many members of the 1st squad are located in building C5?	.23	.18	.30	.43
Are all members of the third squad located in C4 A & B?	.25	.20	.18	.15
What is the location of the unit on your right?	.38	.30	.30	.43
Mean	**.17**	**.20**	**.30**	**.29**

Post-Attack Phase Means:

Question	Mix			
	1	2	3	4
How many OpFor were on the 2nd squad's objective?	.38	.08	.30	.10
Where did the OpFor on the platoon's objective, if any, escape to?	.08	.03	.25	.05
What OpFor activity, if any, had been reported west of McKenna?	.08	.18	.15	.25
In what direction, if any, was the OpFor unit outside of McKenna village reported to be moving?	.20	.13	.23	.48
How many, if any, COBs were on the 2nd squad's objective?	.30	.13	.25	.33
Where is the 2nd platoon's CCP/EPW point located?	.05	0	.50	.10
Mean	**.18**	**.09**	**.28**	**.22**

Planning for the Counter-Attack Means:

Question	Mix			
	1	2	3	4
OpFor size	.65	.08	.68	.63
OpFor preparation	.83	.80	.88	.75
OpFor reinforcement	.23	.28	0	.20
COB disposition	.15	.40	.05	.25

OpFor reinforce approach	.13	.23	.05	.08
Weakest 2nd squad location	.15	.15	.15	.25
Strongest 2nd squad location	0	.45	.53	.03
Building vantage points	.33	.53	.68	.63
Mean	**.31**	**.36**	**.37**	**.35**

Defense Means:

Question	**Mix**			
	1	**2**	**3**	**4**
OpFor reinforcement	.43	.50	--	.63
OpFor activity	.15	.38	--	.30
OpFor location	0	.15	.15	.65
OpFor unit direction	.28	.38	.10	.18
OpFor reinforcement capability	.43	.45	.03	.55
OpFor intent	.05	.08	.75	.13
OpFor attacking 2nd squad	.25	.40	.50	.33
Mean	**.22**	**.33**	**.31**	**.39**

Means for all Phases:

Mix			
1	**2**	**3**	**4**
.22	.24	.32	.30

	Mix			
Sensors	**1**	**2**	**3**	**4**
Distributed cueing sensors in key locations around the village (acoustic, seismic, magnetic sensors that can discriminate by type, person, vehicle).	Yes			
One hovering/perching Unmanned Aerial Vehicle (UAV) with fixed infrared camera sensor.	Yes	Yes		
Fixed imagers (Acoustic, seismic, magnetic sensors that can discriminate by type, person, vehicle) in key locations inside the village.	Yes	Yes	Yes	
Advanced sensors with autonomous image sensors with automated target detection and classification and autonomous imagers	Yes	Yes	Yes	Yes

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