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Improving Platoon Leader Situation Awareness with Unmanned Sensor Technology

C2 Experimentation

C2 Analysis

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Abstract

We investigated the contributions that unmanned sensor imagery provides to platoon leaders operating in a force-on-force experiment. We followed the platoon leader, platoon sergeant, and Robotics Non Commissioned Officer (NCO) as they conducted reconnaissance missions against a live, unscripted opposing force (OPFOR) in the Ft. Dix, New Jersey environment. Our situation awareness (SA) survey methodology was consistent with the Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 2000). We randomly asked leaders to answer questions about the OPFOR and to draw their locations on a map. We later compared these answers and drawings with computer-generated maps that showed geo-referenced positions of the OPFOR. Our findings indicate that leader SA was higher, in general, when using unmanned sensor technology than when relying upon human intelligence alone. However, the ability of leaders to consistently demonstrate high levels of SA across trials was disappointing. We believe this is due, in part, to the uneven performance of the sensor imagery, the periodic failure of the communication system due to dense foliage of the site, and the inability of the leaders to develop effective tactics, techniques, and procedures (TTPs) for the persistent monitoring of the sensor images and coordination with unmanned sensor operators.

Introduction

The C4ISR On-The-Move (OTM) Testbed was begun in 2001 to allow demonstration, testing and evaluation of Army Future Combat Systems (FCS) emerging technologies (RDECOM, 2005). The 2005 experiment[1] was the second instance of a live force-on-force test of the systems architecture developed to simulate the FCS network[2], and was conducted at Ft. Dix, NJ. The trials were conducted from 8 August through 9 September. Two force-on-force missions were conducted by Soldiers acting as test participants in this time period: a base case and an advanced case. In the base case (conducted over 3 days) the Soldiers, operating in two platoons, conducted independent Intelligence, Surveillance, and Reconnaissance (ISR) missions in separate training areas without the use of the FCS technology (dismounted battle command interface, unmanned sensors and vehicles). In the advanced case (conducted over 5 days), these technologies were available to the platoons. The battle command interface used in this experiment was Force XXI Battle Command Brigade and Below (FBCB2), version 4.4.2. During the base case, the interface was only available on vehicle-mounted screens. During the advanced case, dismounted FBCB2

[1] This event, though considered an experiment, was more realistically a structured field observation where we asked Soldiers to use new technologies in an operational setting. This allowed us to observe new users and record how systems performed in a number of missions (Hawley, 2006).

[2] The Testbed included a set of infrastructure components including a lab-based environment at Fort Monmouth and a field environment at Fort Dix. The former included a modeling and simulation laboratory, a network operations center and a full suite of the Army Battle Command System. The field site included an administrative operations center, a maintenance facility, presentation space and an extension of the M&S laboratory. The test site provided position reporting devices, network sniffers, and audio-visual capture devices that are integrated with the M&S capabilities. For a detailed explanation of these capabilities, see RDECOM; 2005.

tablets were used by Soldiers in addition to the vehicle-mounted displays. This interface allowed the transmission of spot reports, free text messages, and images chipped from sensor video. Also used in the advanced case were unmanned aerial vehicles (UAVs), small UAVs (SUAVs), an Unmanned Ground Vehicle (UGV) and Unmanned Ground Sensors (UGS). The SUAV used was a hand-launched vehicle, compared to the larger machine launched UAVs.

Situation Awareness

SA is the ability to perceive, comprehend, and project actions that might occur in the battlefield environment (Endsley, 2000). This is one of the most critical and challenging tasks in combat today. A vast portion of the Warfighter's job is involved in developing SA and keeping it up to date in a rapidly changing environment. All information that supports SA must be integrated into a concise picture that supports mission accomplishment.

The FCS C4ISR architecture is expected to provide each echelon commander with the combat leverage to coordinate resources, engage and defeat the enemy. C4ISR should provide a common communication connectivity that facilitates the land force commander's ability to synchronize elements to shape the battlespace at tactical levels. The assumption is that with improved SA, the platoon commander can perform mission specific tasks better and more efficiently.

The battlefield poses a variety of challenges to SA such as information overload, nonintegrated data, rapidly changing information, and a high degree of uncertainty. In our observations of the platoon leaders, we were interested in observing and documenting the degree to which FCS technologies impacted situation awareness.

In the networked Army of the future, Soldiers will be required to complete several tasks at a time, and will have to effectively shift among these tasks. Shifting between competing tasks appears to depend on four factors related to the tasks or the task environment: task complexity or the compelling nature of the task, cognitive tunneling (becoming consumed in a task), task importance, and physical salience of task properties or task stimuli (Iani & Wickens, 2004). As the platoon leaders interacted with various technologies, we observed and documented their ability to attend to multiple tasks at once.

Methodology

Before the beginning of the experiment, Soldiers attended a meeting to learn about the goals of the Testbed experiment and become familiar with procedures. The researchers also explained the situation awareness methodology and reviewed the rights of research subjects. All participants reviewed the volunteer affidavit agreement and consented to participate in the experiment. At this meeting, they completed a demographics questionnaire. Also before the experiment, the data collectors responsible for the administration of the SA surveys were briefed on the survey format, administration procedures, and the participants they were to assigned to follow.

Prior to the force on force trials, Soldiers attended two weeks of training. This included classroom training on FBCB2 and field training with the Unmanned Ground Vehicle (UGV) and the Small Unmanned Aerial Vehicle (SUAV).

During the experiment, SA was measured using a modified Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 2000). This procedure is designed to measure an individual's understanding at three levels of perception, comprehension, and projection while focusing on critical mission objectives. On each day of the experiment, six key leaders completed SA surveys at four times. These were before they departed from the assembly area, twice during the mission, and once immediately after mission halt. These leaders were the platoon leader (PL), platoon sergeant (PSG) and robotics NCO (RNCO) in two platoons. Each survey contained questions that asked about enemy locations, size, and possible actions that might be forthcoming. These were open ended questions, and were designed by subject matter experts (SMEs) who were familiar with the mission scenarios. The surveys also contained a map of the relevant mission area and leaders were asked to show locations of all known Blue and Red vehicles and dismounts.

Our data collection included the manual recording of communication events within one platoon. We content analyzed these transcripts to identify the types of communication and system problems encountered. The transcripts provide possible explanations for degraded levels of information quality and situation awareness that might have resulted from problems with network connectivity or system breakdowns.

Results

Demographics

In all, the force-on-force experiment consisted of 64 participants. Thirty members from the 50th Brigade, New Jersey Army Reserve National Guard (ARNG) participated as Blue Forces and 34 contract employees, who were hired expressly for this experiment, participated as the OPFOR.

A demographics survey was administered to all participants prior to the start of the experiment. Survey results indicate that Blue Force participants were highly experienced in that 60% had held a leadership role and 87% have been deployed. These participants had an average of 9 years experience in the Army and represented a predominantly enlisted rank structure; all were enlisted with the exception of one 1LT. All Blue Force participants were male. Only 41% of the OPFOR reported prior enlisted military experience. For those with prior experience, 71% reported Army service. On average, this experienced OPFOR subgroup reported 8.25 years of prior enlisted experience. Of the OPFOR group that reported prior military experience, 24% reported one or more deployments during their Service careers. All of the prior OPFOR military experience was in the enlisted ranks. Two OPFOR participants had obtained the rank of E-8, one achieved E-7, four were E-5, five were E-4, one was E-3 and one was E-2. Sixty-eight percent of the OPFOR reported previous experience in the Fort Dix test range area. The OPFOR was predominantly male (88%) compared to 12% female.

Transcript analysis

The daily transcripts were content-analyzed to determine how tasks were performed, by whom, and what types of problems arose in the conduct of these tasks. We developed several categories to cluster message content. These included breakdowns in equipment, breakdowns due to user issues, and FBCB2 tasks. The first equipment breakdown category was further divided to include radio communications, FBCB2 vehicle problems, FBCB2 tablet problems, and equipment problems with the unmanned vehicles or sensors (e.g. UAV, SUGV, and UGS). We partitioned the category of FBCB2 tasks into spot reports, free text, and viewing images from unmanned sensors. Table 1 shows these categories and the number of communication messages associated with each. The number of messages represents the communications events from all 8 days of the experiment.

Table 1 Factors Affecting Task Completion

Category	Messages	Example
Equipment Breakdowns		
• Radio communications	25	*"Today was a challenge for communications (vegetated area). 3rd squad could hear everyone, no one could hear them. 1st squad comms were intermittent at best."*
• FBCB2 vehicle	6	*"FBCB2 screen keeps cutting out, possibly due to heat from engine."*
• FBCB2 tablet	10	*"I have tablet out, but can't send information. When I put the pen on the screen it is 4 to 5 inches to the left of where I need to mark, the cursor moves in its own direction."*
• UAV	9	• *Engineers trying unsuccessfully to open UAV spot report images, believe it is a technical failure.* • *Images on spot report are blurred to point of being unrecognizable*
• SUGV	1	*When using SUGV, it was within 50 meters of target vehicle, but didn't detect due to constraints of sensor movement.*
• UGS	1	*PL is advised to look at UGS field. Opens one image (takes 13 seconds). Opens second image (takes 17 seconds). PL misinterprets retreating OPFOR vehicles as reinforcing force. Time pressure and lack of regular monitoring of UGS field led to confusion with images.*
User problems		
• Dismounted reports to leaders	10	*"Any 2nd squad element, this is Platoon Leader, somebody get me a sit rep." [from 2nd squad]: "Standby." "I need a sit rep from anyone. Who's next in that chain of command? Squad 1, is there anyone left alive in that unit?"*
• Use of subordinate team leaders	8	*Platoon leader stops RNCO from downloading UAV images because it is interfering with his attempts to download and view. Lack of task management.*
FBCB2 interface		
• Spot reports	15	*All squads are sending spot reports to PL from their tablets.*
• Free text	4	*PL sends priority information requirements report to Company Commander in free text.*
• Opening images	6	*Images take a long time to open, often will not open at all.*

In our review of Soldiers' communications and our observations during missions, we noted that it was extremely difficult for them to switch between tasks in a coherent and coordinated fashion and that it was nearly impossible for them to conduct several tasks at once. Task switching became a problem especially when the PL did not efficiently use his subordinates. Early in the experiment, the PL took responsibility for opening and viewing images received from unmanned sensors (this was a responsibility of the Robotics NCO). Frequently, these images did not open right away due to network problems. This required the PL to initiate several attempts to open the message. Because the PL did not monitor the unmanned sensor images on a continual basis, he had difficulty interpreting the image (e.g. were the vehicles in the sensor field reinforcing or retreating?). In this case, the RNCO was underutilized and the PL was susceptible to making poor decisions based on uncertain information. The PL's efforts to download the UAV images and his interest in directing dismounted assets on the FBCB2 display kept him from attending to other tasks. We noted that cognitive tunneling (becoming consumed in a task) appeared to be the major reason that leaders were unable to switch among key tasks (Iani & Wickens, 2004).

Our observations showed that the PL often became quite involved with the FBCB2 screen in attempts to manage the dismounted troops. The troop locations were marked on the display, and the PL used the radio and free text messages to coordinate troop movement. Due to this concentration on the battle command interface, the PL neglected the unmanned sensors and did not delegate this task to the RNCO. The RNCO, following orders from the PL to stay away from the sensor images (to avoid locking up the network), did not stay in touch with the sensor operators and did not maintain an awareness of sensor images. Thus, when the PL was prompted by experiment controllers to switch tasks and open up the sensor images, a considerable amount of time was needed for the PL and the RNCO to understand the current situation. In fact, on occasion, the PL misinterpreted sensor images because no one had maintained a general awareness of sensor images. A more efficient use of manpower would suggest that the RNCO might be responsible for monitoring sensor placement, filtering images, and informing the PL when actionable information is received.

These examples suggest that the platoon members were using unmanned assets without the benefit of effective TTPs designed specifically for this type of scenario. Procedures for distributing responsibilities for sensor coordination among the staff would have helped the platoon leader manage the mission more effectively.

TTPs for integrating unmanned sensors

As we previously mentioned, Soldiers did not receive field training prior to the start of the experiment that would have helped them develop TTPs for the use of the unmanned assets. As the experiment progressed, we collected observations that will be used to develop TTPs in support of the 2006 experiment. Two key observations are worth noting. First, the platoons did not effectively use the RNCO to coordinate the unmanned assets and monitor the images from these assets. As a result, sensor support was uncoordinated, images were often retrieved late in the fight, and the images were sometimes misinterpreted. [3] Second, we noted that the unmanned air and ground vehicles were easily spotted by the OPFOR, alerting them to the presence of the Blue Force. This knowledge was noted by the Soldiers as a reason to use vehicles, in some circumstances, as decoys. These TTPs will continue to evolve over future trials.

[3] On one occasion, when viewing an Unmanned Ground Sensor (UGS) image, the platoon leader perceived that the vehicles shown in the image were reinforcing the OPFOR position when they were, in fact, leaving.

Situation Awareness

At the conclusion of the experiment, researchers coded SA surveys according to the two criteria of fidelity and accuracy. Fidelity was defined as the completeness of information provided in answers to survey questions and annotations of OPFOR locations drawn on maps. As an example, if a Soldier answered most questions with "uncertain" or "don't know" and the map drawings had no or few annotations, a low score was assigned. Accuracy was defined as the degree to which the leaders were able to correctly identify Red positions on the map. We will discuss the fidelity and accuracy measures and coding in turn.

Fidelity Analysis

Initially, all surveys were evaluated to determine the fidelity of their responses. In this initial review, the two authors coded the surveys by examining the written answers to questions and the associated placement of OPFOR icons on the maps. A coding scheme was developed that grouped responses into categories of low, medium, and high. The grading criteria focused on the respondent's knowledge of the OPFOR as represented in answers to the questions (strength of force, planned actions, type of force), and the detail provided of OPFOR vehicles and locations on the map associated with the SA survey. A low rating was given to a survey in which the subject answered "didn't know" to 75% of survey questions. A low rating was also given to map annotations that were either blank or had very few identifiable markings. The low rating indicated that the respondent had little understanding of the OPFOR. A medium rating was given for those responses that provided more granularity on the OPFOR including some level of detail about the enemy disposition (locations of observation posts, target vehicles, etc.). A high rating was given to a survey in which the subject's responses indicated a solid understanding of the OPFOR and map drawings differentiated OPFOR vehicles, dismounts, and possible counter attack forces.

The analysis of fidelity scores was achieved through an independent and blind assessment by the two coders. We evaluated the probes in groups of 10 and marked each as low, medium, or high. Inter-rater reliability was computed by calculating a percent of scores that had been coded alike. The first group of 20 surveys resulted in an inter-rater reliability score of 45%. At this point the raters discussed their strategies, agreed upon a common scoring metric, and continued with the additional surveys. For the remaining surveys, an inter-rater reliability rating of 85% was achieved. The first group of 20 surveys was recoded according to the raters' improved understanding resulting in a final inter-rater reliability score of 95%.

Of the 116 surveys coded [4], 11 (9.5%) were graded as 'high', 28 (24.1%) as 'medium', and 77 (66.4%) as 'low'. Of the 11 high ratings, 9 occurred in the advanced case runs. From the initial set of surveys, we selected a subset for further analysis. We selected those surveys that had a fidelity rating that was either medium or high, or was low and improved over the course of the mission.

[4] We had a number of surveys that were not completed. Each survey included four sets of identical questions that were asked at random times during the mission.

In our analysis of fidelity ratings, we used frequency distributions to compare SA fidelity ratings by case, role, and platoon. We were unable to use inferential statistics due to the low number of subjects and the lack of independent observations.

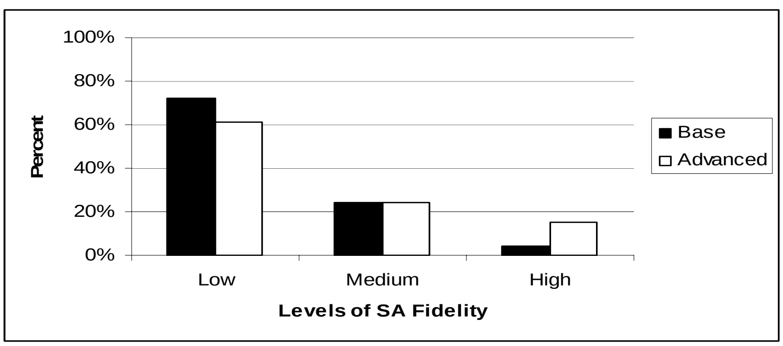
Fidelity ratings by Base or Advanced Case

As shown in Table 2 and graphically in Figure 1, most fidelity ratings for the base and advanced cases fell in the low range. There was a slight improvement in medium scores in the advanced case, and a larger improvement of high scores in the advanced case. Because the fidelity score is essentially a measure of how completely the subject answered the survey questions, we can suggest that the improvement in the high scores during the advanced case is possibly due to the FBCB2 interface. This system allowed the PL to track the dismounts and reported OPFOR locations. These percentages displayed in Table 2 are shown in Figure 1.

Table 2 SA Ratings by Level of SA Fidelity and Case

	SA Fidelity Rating					
	Low		**Medium**		**High**	
Case	***N***	**(%)**	***N***	**(%)**	***N***	**(%)**
Base	39	(72%)	13	(24%)	2	(4%)
Advanced	38	(61%)	15	(24%)	9	(15%)
Total	77	(66%)	28	(24%)	11	(10%)

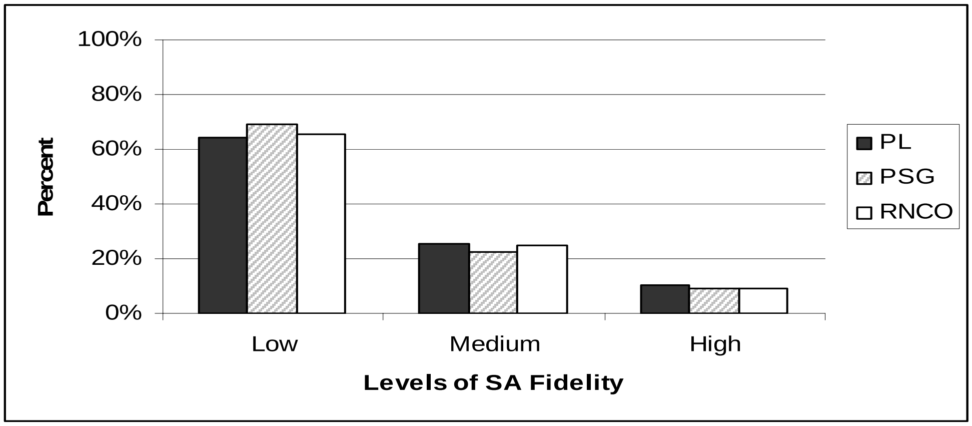
Figure 1 Percentage of SA ratings by level of SA fidelity and case.



Fidelity Ratings by Role

We examined SA fidelity ratings for principal leadership roles. As shown graphically in Figure 2, the fidelity ratings were fairly consistent among the three roles. In general, SA fidelity scores were low for all leaders.

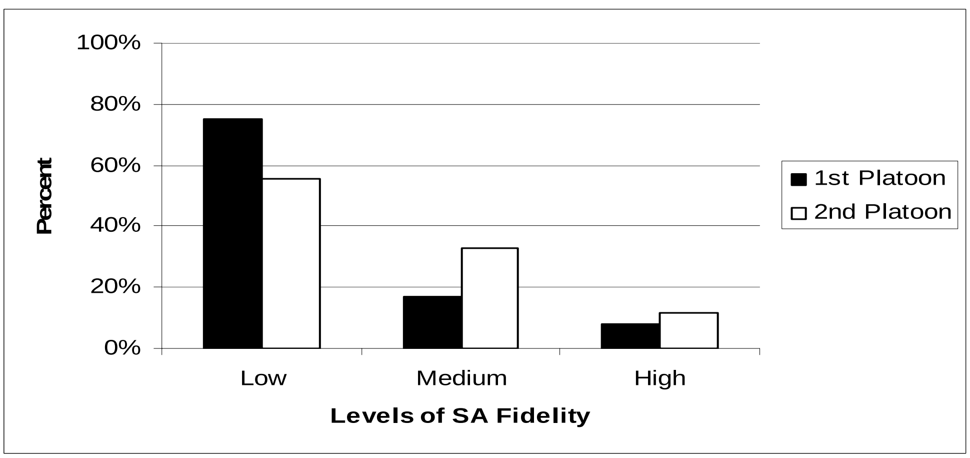
Figure 2 Percentage of SA ratings by level of fidelity and role.



Fidelity Ratings by Platoon

The fidelity ratings showed an interesting pattern by platoon. As shown graphically in Figure 3, the second platoon achieved fewer low scores and slightly more medium and high scores.

Figure 3 Percentage of SA ratings by level of fidelity and platoon.



Although the Blue Forces had a fairly consistent low perception of the OPFOR's location and strength, the fidelity analysis indicates that Blue knowledge of the OPFOR improved slightly during the Advanced Case trials when imagery from unmanned air and ground vehicles became available and leaders were able to use FBCB2 on dismounted tablets.

Accuracy ratings

Accuracy ratings for the 24 surveys selected for the fidelity analysis were completed by comparing the map annotations of the OPFOR positions against the ground truth grid coordinates that were recorded during the experiment by controllers. One of the authors reviewed the map drawings completed by the leaders and compared these to screen shots from the relevant day and time that the survey was completed. These screen shots depict Red vehicles and dismounts in the tactical area, and are the result of GPS transmissions sent from equipment installed in each vehicle and each backpack carried by a dismounted Soldier.

To grade the scores, the SME raters assigned scores in quartiles between 0 and 1 (e.g. 0, .25, .5, .75, and 1.0). These scores were based on the number of enemy identified and the percent correct. For example, if a participant identified two enemy locations, and only one was in close proximity to actual red placement, the resulting score would be .5.

The data in table 5 show the spread of accuracy scores when compared to the fidelity scores.

Table 3 SA Survey Ratings by Fidelity and Accuracy Scores

	SA Fidelity Rating					
	Low Fidelity		**Medium Fidelity**		**High Fidelity**	
Accuracy Scores	***N***	**(%)**	***N***	**(%)**	***N***	**(%)**
1.00	1	(17%)	3	(50%)	2	(33%)
0.75	1	(20%)	2	(40%)	2	(40%)
0.50	1	(11%)	8	(89%)	0	–
0.25	0	–	5	(100%)	0	–
0.00	18	(69%)	3	(12%)	5	(19%)
Total	21	(41%)	21	(41%)	9	(18%)

These data indicate that if a survey was rated low in SA fidelity it would most likely be judged as inaccurate. In general, participants exhibiting low SA fidelity were unable to provide specific information about the enemy and were unable to identify OPFOR positions on a map. However, several SA surveys were scored in the medium and high range for fidelity, but received an accuracy score of “0”. In these cases, participants thought that they knew some fairly detailed enemy information, but were, in fact, incorrect in their beliefs. Approximately 20% of the participants’ surveys received a score above .5 on accuracy, and the majority of these surveys received medium and high fidelity ratings. Surprisingly, five high fidelity surveys were completely inaccurate (receiving a score of 0).

When we analyzed these data further, we realized that in general one platoon was over-represented in the accuracy ratings. This is a function of generally low fidelity ratings for that platoon. The reader will recall that the fidelity ratings provided selection criteria for accuracy ratings. These low ratings could be the result of several factors at play in the experimental environment rather than internal to platoon participants. As the experiment progressed, the Testbed experienced problems with Soldier participation (i.e., mortality). [5] Declining numbers of participants made it difficult to fully field two platoons, and one platoon became the fielding force for the other. Though the platoon with reduced manning continued performing their missions, they did so at an increased cost to their personnel. The fact that this group was able to

[5] The participants in the experiment were members of the NJ ARNG and completed their two week annual training at this time. However, due to the length of the experiment (five weeks), the Soldiers were asked to extend their commitment for extra pay. This commitment became difficult for some Soldiers to meet and resulted in declining participation over time.

successfully complete missions speaks to the professional attitude and perseverance of its leaders and members. However, it can be reasonably expected that battlefield status information received by leaders was degraded (e.g., reduced in number and quality, and received less frequently) due to a reduction in personnel and over-tasking of key leaders. For these reasons the remainder of this section deals exclusively with the leaders of one platoon.

As we investigated the accuracy of SA in finer detail, we realized that one leader in particular provided the best opportunity to test this SA scoring methodology and extrapolate possible understanding in relation to actions. We present descriptive data on this leader as an example of the best development of situation awareness achieved in this experiment.

Table 6 shows the fidelity and accuracy scores by day for the selected leader. This leader did not complete a SA survey on every day of the experiment. These data show that the fidelity scores remain generally consistent with the exception of day 5. The accuracy scores for this leader were highest on days 2, 5, and 6. We suggest that the higher accuracy scores on days 5 and 6 were due to a combination of the FBCB2 interface available on tablets and an improved use of the unmanned sensor images. As the experiment progressed, the leader appeared to become more familiar with the unmanned technology and the images available from the sensors.

Table 4 Fidelity and accuracy scores by day for selected leader

Case	Base Case			Advanced Case		
Day	**1**	**2**	**3**	**4**	**5**	**6**
Fidelity	0.40	0.50	0.50	0.50	0.77	0.53
Accuracy	0.25	0.50	0.38	0.38	1.00	0.75

Conclusions

The participants in this experiment were alike in their experience levels, service affiliations, and their knowledge of FCS technologies. On average, the group had 9 years of enlisted experience in the Army.

The platoon transcripts demonstrate that network connectivity was a sporadic but pervasive problem. The dense foliage of Ft. Dix and the hilly terrain undoubtedly contributed to network outages. System problems also contributed to platoon efforts to prosecute the ISR mission. Examples of these include loss of radio communications, inability of the UAV to launch on time, and inability to transmit unmanned sensor images on a consistent basis. Providing the participants more time to practice tactical missions with the equipment could have alerted us to some of these problems. This is a strong recommendation for future trials.

SA was generally low among all participants. High fidelity scores were greater in the advanced case (15%) compared to the base case (4%), but most ratings fell in the low and medium ranges. We found no differences in the fidelity scores by role, suggesting that the PL, PSG and RNCO all had approximately similar levels of SA. This might be explained by the tendency of the PL to station these players in close proximity. One platoon received lower fidelity scores than the other. We are at a loss to explain this trend but suspect it could be a result of differences in the emphasis on data collection. The accuracy scores for the PL were generally uneven, but were slightly higher in the advanced case.

Most test participants were unable to answer questions about the enemy force and were unable to locate OPFOR positions on a map. SA did improve slightly in the advanced case, when leaders had the benefit of the unmanned sensor images and the FBCB2 tablets for dismounts. Unfortunately, due to our limited data, we are not able to associate improved SA with the use of the new technologies. The noted improvements were marginal and were generally restricted to the platoon leader. Two possible problems may account for the low levels of SA. First, data collected on the SA surveys was, at times, not complete. Providing expanded data collector training on administering the surveys and improved emphasis with the Soldiers on the importance of this type of survey could have improved the completeness of the data collected. At times, the Soldiers completing the surveys did not appear to put much effort into the map annotations, possibly because of their fatigue or their lack of patience for completing four surveys each day. Some data collectors who were responsible for the SA surveys were also responsible for other activities, possibly causing them to be distracted from the SA survey administration.

The second probable cause of the overall low SA was the recurrent problems with network connectivity that resulted in delayed image transfers from the unmanned assets to the FBCB2 displays. These problems could have discouraged the platoon leader from expending his time on monitoring the images, choosing instead to focus on his human dismounts.

The FBCB2 tablets, though not without problems, did give the PL a better view of how the dismounted troops were positioned and how maneuvers were progressing. Unfortunately, the PL became so involved with this aspect of the interface, and neglected other important tasks (such as UAV or UGS images and communications). This problem could have been moderated through the improved use of the RNCO position. TTPs that define RNCO duties and capabilities are needed and should be developed in support of future Testbed experiments.

Our findings suggest that while unmanned assets clearly provide benefits to the tactical force, the use of these systems extracts a cost to units in the form of additional physical and cognitive demands. Continued efforts to develop robust communication networks and TTPs for coordinating these systems into the dismounted force should be aggressively pursued. A primary focus area for future research is an improved understanding of how unmanned assets can enhance human decision making in uncertain and complex terrain.

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