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“C2 and Agility”

Automatic Alerts in Net-Centric C2 Systems: Effects in the Situational Awareness

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Topic 8: C2 Assessment Tools and Metrics

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Abstract

Network-centric-warfare translates information superiority into combat power by effectively linking knowledgeable entities in the battle space. This advantage, allied to the modern resources of Telecommunications and Computer Science, allows greater agility in the decision cycle and helps enhancing the situational awareness (SA). With the increase in the amount of information made available, it might be important to consider a system of automatic alerting for data monitoring and to provide notifications when critical events occur. However, experiments with these systems, in other areas, have shown that alert automation can, paradoxically, contribute to the reduction of SA. During high stress or high workload periods, alerts may actually become intrusive, and responding to them can increase workload and shift the operator's attention. This work shows the result of an experiment that informs as SA varies when we use a system that generates automatic alerts. Participants operated a simulation of a net-centric system, the "C2 em Combate" Brazilian Army software, which was modified to include an automatic alerting system. SA was measured both with the alerting system enabled and disabled, and the results indicate when automated alerting systems do improve or not the user SA. The results can be used to help designing automated feedback in C2 systems.

Keywords: Net-Centric Warfare, Alerts, Situation Awareness.

INTRODUCTION

The sharing of information over a computer network is becoming a common means of communications in many fields. Armed Forces have taken advantage of this technology to improve the performance in activities of Command and Control (C2) in military operations. For example, commanders in battlefields geographically away, but communicating itself through a network, can attend the events of the maneuver in a computer screen almost in real time [1].

The use of networked computers to enhance agility in C2 has opened new possibilities. Data can be analyzed by computers and results displayed to leaders, providing them better information on which to base decisions. Leaders can be provided with immediate feedback about their performances. A promising technology would be a computer system to monitor the data stream and provide alerts when critical events occur to ensure they are not missed by the operator.

As well as the troops gain more experience in net-centric digital C2 systems, more functionality is required and added to the systems. Features such as the automated alert system, mentioned above, can help direct the user`s attention to important events and increase the Situational Awareness (SA).

Situational Awareness always is associated with the monitoring of the maneuver in a military operation, but more than this, SA, is basically a "cognitive human state" [2]. This state is constructed with information from many sources and is affected by factors such as personality, fatigue, load of work (mental workload), fear, etc.

However, experiments in other areas with systems that aim at driving SA through alerting have shown that automation can, paradoxically, contribute to the reduction of SA. During high stress or high workload periods, alerts may actually become intrusive, and responding to them can increase workload and mistakenly shift the operator's attention. This raises the question of whether immediate feedbacks enhance SA or interfere with SA. This work shows the result of an experiment on C2 that informs as SA varies when we use a system that generates automatic alerts. Participants operated a simulation of a net-centric system, the "C2 em Combate" Brazilian Army software, which included an automatic alerting system. SA was measured both with the alerting system enabled and disabled, and the results indicate when automated alerting systems do improve or not user's SA. These results can be used to help designing automated feedback in C2 systems.

In the first part of this paper we explain the concept of SA as an important cognitive measure for C2 systems operators.We then explain how to measure SA and why we choose the Situation Awareness Global Assessment Technique (SAGAT). A brief description of the software used for the units of the Brazilian Army is provided, and then we explain some concepts about the alerts system used in the experiment. The second part of the paper details the experiments and the results obtained, and finally the last part presents the main conclusions. An example of a SAGAT questionnaire is presented in the Appendix.

BACKGROUND

SITUATION AWARENESS

It is critical that human operators have an awareness of what is happening in C2 situations, so that they can understand the tasks they are conducting and the context within which they are working.

In the 1950s, the U.S. Air Force coined the winning element in air-to-air combat engagements in Korea and Vietnam as the "ace factor" or what they called having good situation awareness [3]. Since the term SA originated, it has expanded to include almost any domain that involves humans performing tasks on complex, dynamic systems. As applications have spread and increased, so have SA definitions and measurement techniques.

Some SA definitions are human-centric, others are technology-centric, and some encompass both the human aspect and the technology, but all generally refer to knowing what is going on and what will happen next. SA is important because it frequently guides decision making and action [4]. The most widely accepted definition is Endsley's human-centric interpretation [5] that "situation awareness is the perception of elements in the environment within a volume of time and space (level 1), the comprehension of their meaning (level 2), and the projection of their status in the near future (level 3)" (refer to Figure 1).

Military and C2 applications, often refer to SA as knowledge of the physical elements in the environment (equivalent to Endsley's level 1 SA), while the other levels (equating to levels 2 and 3) are referred to as situational understanding and assessment [6]. Technology-centric definitions of SA are linked to C2 applications insofar as they often refer to the quantity and quality of the information provided by the technology and include data visualization [7].

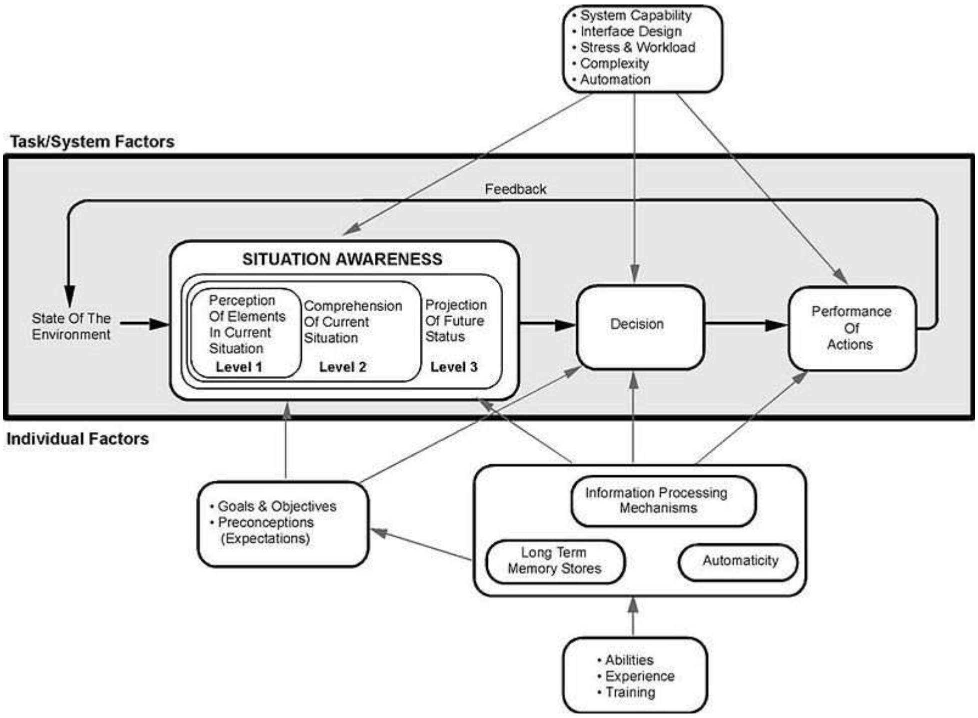

Figure 1: Endsley's Model of SA

Human-system definitions have recently gained maturity and popularity and relate the information provided by the system to the information needed by the operator. Miller and Shattuck's model leverages Endsley's human-centric definition and the lens concept in a multi-step process shown in Figure 2 [8].The left hand side illustrates the technology part of situation awareness while the right hand side represents the human or cognitive situation awareness. As can be seen, some amount of the information from the world is detected by sensors and some amount of that information is made available to the human, who then perceives the information being displayed, comprehends or makes sense of that information, and finally uses it to predict what will happen in the world.

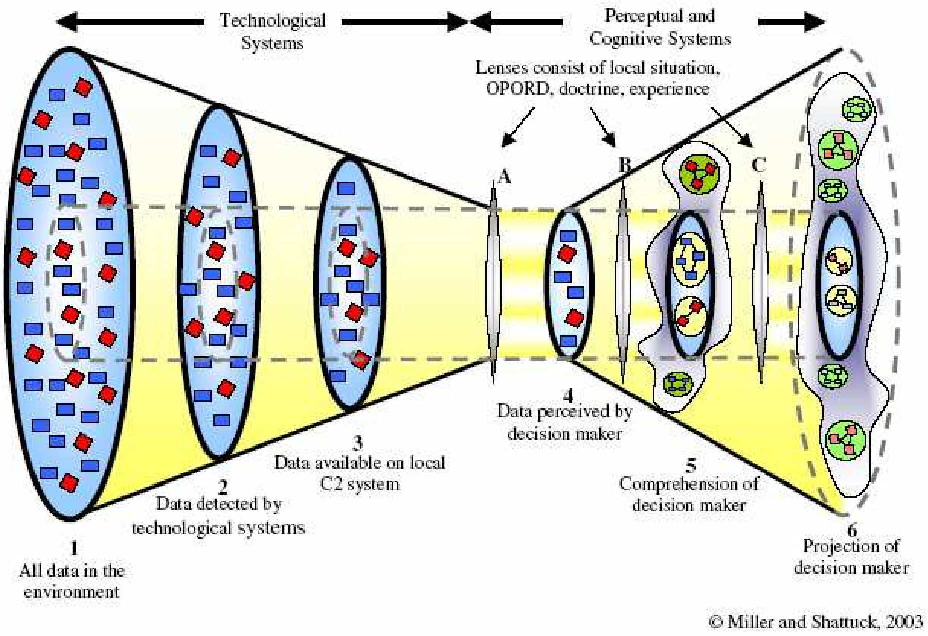

Figure 2: A Dynamic Model of Situated Cognition

No matter the SA definition, SA is challenging to measure. The information that is required at a particular time and in a particular situation depends on the current goals and objectives of the C2 organization, which are often dynamic. Even when all information is accessible, only a subset of that information is needed to plan and assess the current goals and objectives. Finding the right information at the right time to be aware of what is happening is a challenge, as is gathering pertinent information to be able to make a decision. In complex, real world scenarios, it is critical that SA measurement questions and methodology are tailored to the domain and context in which they will be used.

SITUATION AWARENESS MEASURES

Various methods have been developed for measuring situation awareness particularly in the aviation domain [9]. These include performance based measures, subjective techniques and questionnaires/queries. An example of a performance based measure for a Brigade Headquarters may be the battle outcome, such as the loss exchange ratio. Such measures are attractive because they are objective, non-intrusive and are generally easy to obtain. However, in a complex environment, they lack sensitivity and diagnostic value since factors other than situation awareness are likely to contribute to performance. Subjective ratings of situation awareness by the participants may be inaccurate because the subjects may not be aware that they are missing information. Observer ratings may be more valid if the observers know the situation intimately and if they are trained in observing the participants' behavior. The non-intrusiveness of observer ratings works in its favor. Questionnaires administered after an exercise can be misleading due to the delay between the time when the events occurred and that of questioning.

Because of the limitations in the various methods outlined above, the direct questioning technique based on SAGAT (Situation Awareness Global Assessment Technique) was used. SAGAT involves interrupting the simulation at random times during which subjects are questioned. The responses to the questions or probes are compared to the situation in the simulation at the time of the interruption. This comparison makes the technique less biased than self-ratings or observer ratings of situation awareness. SAGAT contains a set of probes that are relevant to the domain being studied. These probes, which cover all three levels of situation awareness, are based on the situation awareness requirements for the task. From the set of probes a random subset are asked during a freeze. This randomization is necessary so that participants do not selectively pay attention to the issues raised in the previous freezes. Randomization also emphasizes the need to cover all aspects of the situation in the probes, rather than only asking highly significant questions [10].

The development of the situation awareness probes for SAGAT involved a three stage process (Figure 3). These critical SA requirements can by identified utilizing a Goal Directed Task Analysis (GDTA), a unique form of cognitive task analysis that involves conducting extensive knowledge elicitation sessions with domain subject matter experts [11]. The objective of the GDTA is to identify the major goals and decisions that drive performance in a particular job/position as well as to delineate the critical, dynamic information requirements associated with each goal and decision [12]. Interviews were conducted with Army Officers to elicit the cognitive processes in conducting their tasks. Analyses of the interview results identified a list of the information required for situation awareness. This was in turn used to formulate the situation awareness probes. In addition, we found several examples of cognitive task analysis for several Army Brigade staff positions (Intelligence (S2), Operations (S3), Logistics (S4), and Engineer) to define the goals, decisions, and information requirements relevant to successful mission completion with respect to each specific position [13].

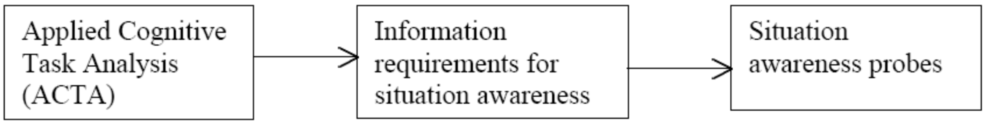

Figure 3: The process for the development of situation awareness probes.

NET-CENTRIC C2 SYSTEMS

Networked C2 systems provide to the commander, together with its bigger state, to carry through tasks that before were executed manually or for applicatory programs that were not specific. For example, the planning of missions using a mosaic of topographical maps contend the battlefield and acetates as maneuver showing the areas of obstacles, forces friends and enemies, amongst other information, can be made using digital maps and layers of visualization with filters.

The digital age increases not only the combat capacity, but also the security by reducing fratricide possibilities or incidents involving friendly elements [1]. It is expected that units of combat that use digital systems keep better SA for faster planning and execution operations then the ones that do not use them.

Digital C2 systems help to visualize the battlefield and supply information in formats that help to increase the SA of the commander. They are provided with analytical tools with proper language and symbols, as analysis and filtering of the land, that automatically contribute with the SA without necessity of clarifying texts.

There are many different digital C2 systems. Some are specific for determined activities, as intelligence, support of fire, logistic, etc. Others can operate on many activities and be observed by specialists, each one using the system from his or her specific point of view.

The Brazilian Army uses "C2 em Combate" as network C2 system. It is constituted of decision support program and by centers of Interface and Integration (CII) called "Telematic Modules". Information on the tactical situations can be distributed around the infrastructure of communications that is mounted with CIIs. A screen is shown in the Fig. 4.

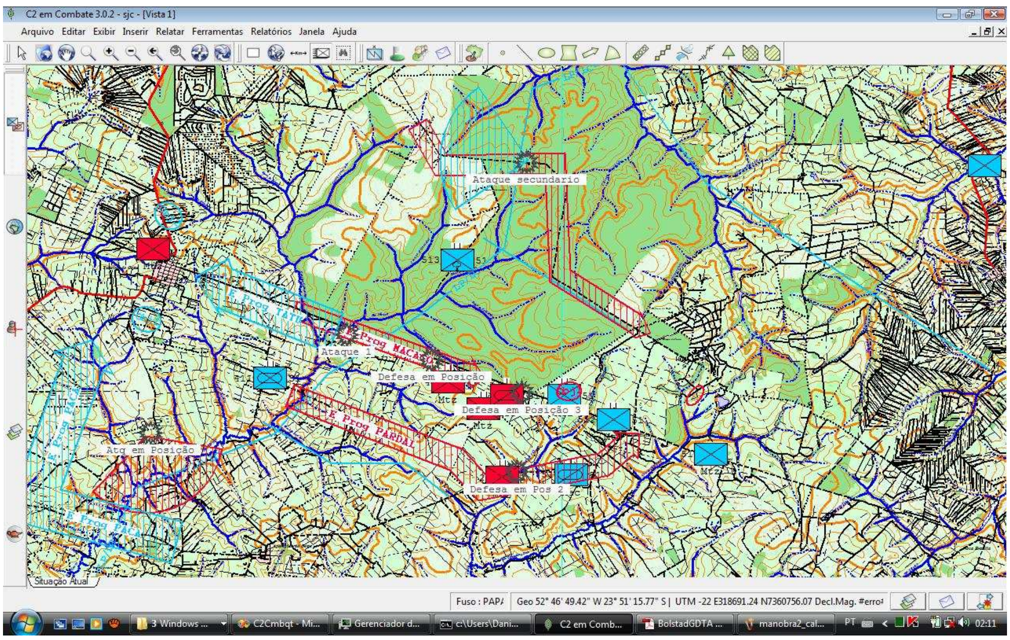

Fig. 4. Screenshot of the "C2 em Combate" program.

Presentation of a map for graphical visualization of the maneuver allows inclusion of unfolding of the friendly and enemy forces; zones of action and objectives and other measures of coordination and control (Limits, Points of Meeting etc.). It is also possible to consider fragmentary orders, reports, plans and messages.
The program thus presents a dynamic vision of the battlefield. Units endowed with Global Positioning System (GPS) automatically bring up to date its position, sent by the network according to a protocol of response and distribution of the information, in a way that the image can be rendered in real time in all the machines that are connected. As a result, the commander can spend less time in identifying and getting knowledge of the situation, and more time in planning and executing the action lines.

AUTOMATED ALERTING SYSTEM

An automated alerting system is a tool used to monitor the data and to provide alert when critical events occur, with the purpose of guaranteeing that these are not forgotten by the operator. In fact, an important consideration is that operators who visualize computer screens might fail in detecting changes that occur on those displays, in a phenomenon called change blindness.
Change blindness tends to occur concurrently with various types of visual transients such as icon movement, screen flashes or eye blinks. In addition, operators may fail to detect changes if they are performing others tasks or working in a given level of zoom and alterations happen outside his or her area of vision. Individuals tended to detect changes in icon appearance/ disappearance and color changes, but have more difficulty detecting changes in icon type and movement, particularly if the icon was in the periphery of the screen and the movement has small amplitude.
The concept of change blindness is related with a system of alarms in two forms. First, alerts can call the attention for critical events that the operator of the system is not monitoring. Second, alerts can “blind” the operator capturing its attention at inopportune moments. Both effects influence the SA of the operator.
The “C2 em Combate” software can store all the inserted information, also with an evaluation of the information source, but it does not possess an automated alerting digital system.
A new software component was then developed to be connected to the “C2 em Combate”. Named Intrusion Alerts Automatic System (IAAS), it adds automatic alerts functionalities to give support to Analysis After-Action (APA) of operational exercises. IAAS allows configuring the type of alerts to be monitored for each specific machine. It also allows the user to decide when the alert must be gone off. For example, using the IAAS a unit can be informed when it gets close to an enemy (see Fig.5).
IAAS provides information in text format and can store the operator decisions as a reply to any alert. The user can also ignore the alert and keep it, or even erase it. IAAS keeps a record that allows the user to recoup an alert or send it as data for the APA. The operator can keep an alert during a period of high workload and subsequently recoup it to see if it still remains, that is, if the situation that motivated the alert continues.

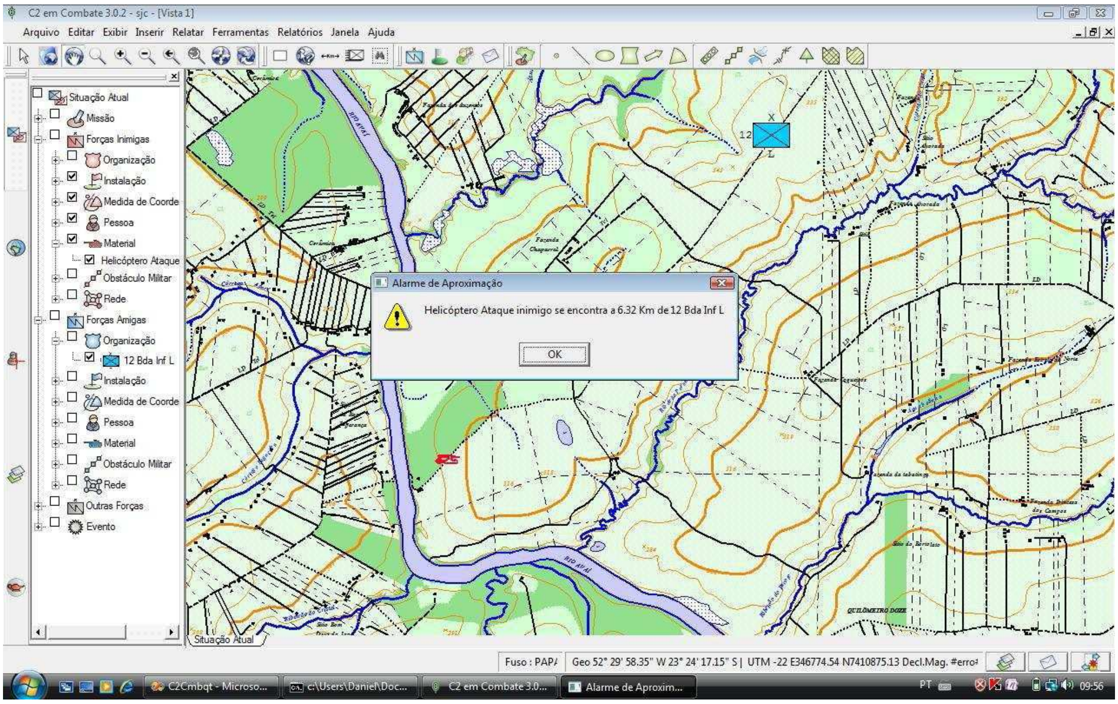

Fig. 5. IAAS alert example.

EXPERIMENT

METHOD

Participants: fifteen Brazilian Army Soldiers. The mean age was 37,2 (SD = 4,2), with averaged 17 years (SD = 4,6) of military experience. Ranks ranged from Sergeant to officer. None of the Soldiers had prior experience with “C2 em Combate”.

Materials: A simulation of a networked C2 system was presented on a laptop computer (Core 2 Duo) using a 14" graphics monitor operating under 1280 by 800 pixel resolution. The C2 system simulated was the “C2 em Combate”. The simulation presented a map display showing locations of friendly units, enemy units and battlefield graphics such as phase lines, unit boundaries, obstacle belts, etc. For the purposes of this experiment, three Army training scenarios were programmed, namely a practice scenario and two full length experimental scenarios, each based on different topographical maps and orders of events. A screen of the experimental scenario is shown in Figure 4. The experimental scenarios were based on real operations, standing out the point of view of a Brigade of Infantry in military operations.
A simulation of IAAS ran concurrently with the “C2 em Combate” task during experimental trials. The current experiment employed IAAS alerts triggered by five significant events: unit approaching a minefield, receipt of an enemy report, a new friendly unit appearing on the display, approach of enemy units, or a unit approaching a nuclear- biological- chemical (NBC) contaminated area. The IAAS system has a number of other features which were not used for this research as they would have added unnecessary complexity to the experiment. This experiment employed IAAS textual alerts, but it did not include graphical alerts or other capabilities. Further, participants were required to interact with the alerts to remove them from the screen. The features used were the visual alerts.
Workload was varied by manipulating task difficulty, defined as the number of significant events (i.e., minefield, enemy report, etc.). In one “C2 em Combate” scenario, the task difficulty per time interval, was low, whereas in another scenario was high. A low difficulty

condition had on average 1 event every 30 seconds (10 total events). The high difficulty condition had on average 1 event every 20 seconds (20 total events). The order of significant events was randomized with the constraint that each type of event appeared equally as often as the other events.

Participants' SA was measured using the SAGAT. Example queries included recalling the approximate number of friendly units currently on display and drawing conclusions about which objective the commander's unit (icon) is heading towards. For an example of a SAGAT questionnaire please see Appendix A.

At the end of the experiment participants completed an exit questionnaire, which asked participants their opinion of how the alerts affected their performance or how they may affect the performance of others when using “C2 em Combate”. Responses were made on an agreement scale (1 = Strongly Disagree; 4 = Strongly Agree).

Procedure: After completing an informed consent and demographics questionnaire, participants were asked to complete a training session, which informed them about their task during the experiment and introduced them to the basic information they would need on “C2 em Combate” and automated alerts. Following the training, the participants were given a training evaluation; this evaluation ensured that they understood the task and the basic information on “C2 em Combate” and IAAS needed to complete the task. After successfully completing the training, participants were given a six-minute practice scenario followed by the SAGAT questionnaires to familiarize them with how the experiment would proceed. An explanation of SAGAT procedures and detailed instructions for answering each query was also provided before testing.

Participants then completed two experimental sessions of approximately 12 minutes each.

During the sessions they were asked to view the “C2 em Combate” display and monitor it for significant events. For one session, alerts were enabled, while for the other session alerts were disabled. The conditions (alerts enabled or disabled) and scenarios (which of the programmed “C2 em Combate” scenarios they observed) were counterbalanced, creating four possible orders.

At pre-programmed intervals of every six minutes, the “C2 em Combate” simulation was halted and the display replaced by a blank screen. Immediately after the simulation was stopped, the SAGAT questionnaire were administered to the participants. After the participants completed the questionnaires, they continued monitoring the “C2 em Combate” display from the point at which it was stopped. These stops were repeated two times for each 12 minute scenario; this number was chosen based on Endsley report that no decrements of performance with up to three stops within a fifteen minute period are significant [5]. In all, there were two SAGAT measures for each “C2 em Combate” session, for a total of four measures for the two sessions. The participants were instructed to attend to their tasks as they normally would, with the SAGAT queries considered as secondary.

The questions on the position of all the elements of combat simulation for the operator were of greater responsibility. The great changes in this level of data would be most significant in influencing the decision of the commander. Following the two sessions, participants were asked to complete the exit questionnaire.

RESULTS

Participants were asked on several aspects of the situation executed, and all the SA levels were evaluated. The SAGAT performance results are displayed in Figure 6. We examined the equivalence of the two “C2 em Combate” scenarios. Scenarios A and B corresponds to the two different infantry operations. In the vertical axis we show the percentual SAGAT scores for the questionnaires. Both scenarios were evaluated with and without alerts.

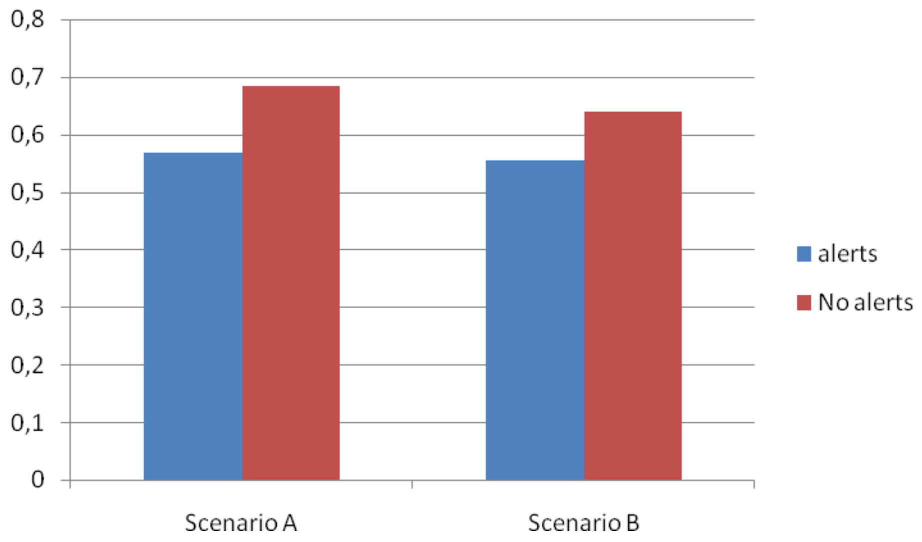

Fig. 6. SAGAT performance.

We also constructed histograms that show the frequencies distribution with and without the use of alerts (Figures 7 and 8). In the horizontal axis we have the percentage of SAGAT scores and in the vertical axle the number of subjects who reached that score.

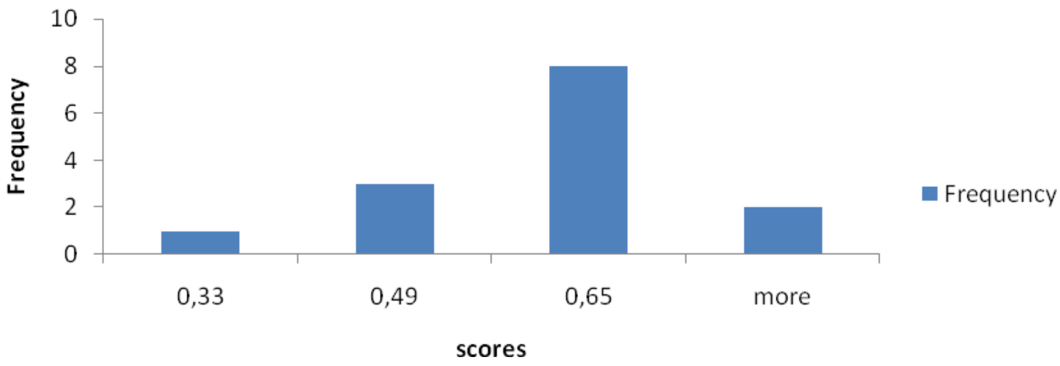

Fig. 7. Histogram with alerts system

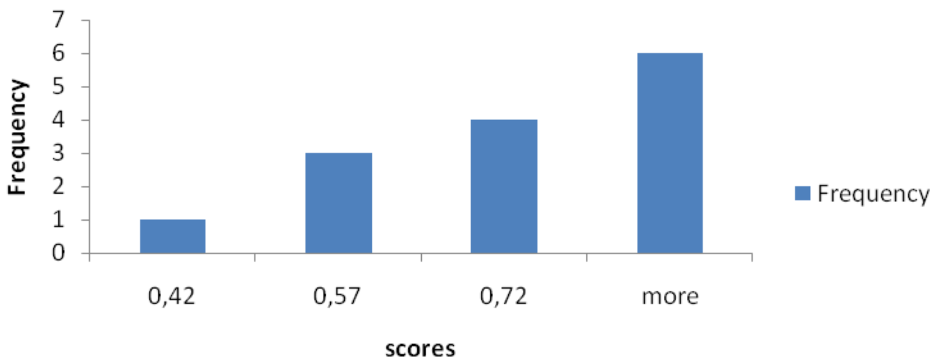

Fig. 8. Histogram without alerts system

The graphs indicated that the two conditions (with and without alerts) produce significant differences with respect to SAGAT performance. For statistical validation, we verified if the means of the samples are equal. Before this, we carry through a F-test to examine if the samples had the same variance. The results are in Table 1.

	With Alerts	Without Alerts
Mean	0,561428571	0,665
Variance	0,013705495	0,021665385
occurrences	14	14
df	13	13
F	0,632598717	
P(F<=f)	0,210009109	
F critical	0,388059098	

Table. 1. F-test , two samples

How the F value ≅ 0,633 is greater than F critical ≅ 0,388, we can consider the same variability for the two samples. We then applied a t-test to verify if the means are equal (results in Table 2).

	With Alerts	Without Alerts
Mean	0,561428571	0,665
Variance	0,013705495	0,021665385
occurrences	14	14
Variance group	0,01768544	
Hypothesis	$\mu 1-\mu 2=0$	
df	26	
Stat t	-2,060540037	
P(T<=t) one-sided	0,024741902	
t critical one-sided	1,705617901	
P(T<=t) two-sided	0,049483804	
t critical two-sided	2,055529418	

Table. 2. T-teste: two samles, variances equivalents, α=0,05

The result show that the value |T| ≅ 2,06 and T critical for two-sided ≅ 2,055 are to next, because this is difficult say that the means are equal or different. However if we want to evaluate, only, if the mean of the results with the use of alerts is equal or below the mean without the use of alerts, with a confidence level of 95% we can discard the null hypothesis and argue that the mean performance from the use of alerts is lower then when the alerts are disabled.
To better examine SAGAT performance and verify the influence of the two different scenarios, we carried out an ANOVA with two conditions of alerts and the two scenarios.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
scenario	1	0.05316	0.05316	0.7053	0.40928
alerts	1	0.27087	0.27087	3.5941	0.07009
scenario:alerts	1	0.00688	0.00688	0.0912	0.76521
residuals	24	1.80874	0.07536		

Table. 3. ANOVAT with two alert conditions and two scenarios

The results confirm that scenarios A and B can be considered equivalent, that is, although they represent simulations of different operations, the difficulties are similar. On the other hand we

can consider that the use of alerts reduce SAGAT scores, that is, the results show that when we use an alerts system the SA decreases.
Another interesting result consider both the use of alerts and the workload conditions (Figure 9).

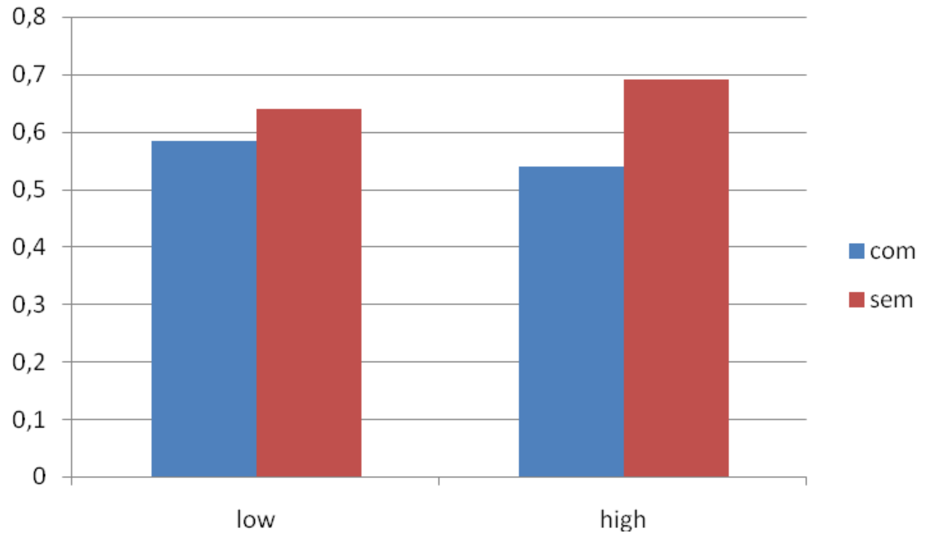

Fig. 9. SAGAT with alerts and workload conditions

For analyzing the results we carried out two t-tests, one for low and another for high workload. Results are in Tables 4 and 5.

	With Alerts	*Without Alerts*
Mean	0,538571	0,691429
Variance	0,017275	0,022552
occurrences	14	14
Variance group	0,019913	
Hypothesis	0	
df	26	
Stat t	-2,86592	
P(T<=t) one-sided	0,004064	
t critical one-sided	1,705618	
P(T<=t) two-sided	0,008129	
t critical two-sided	2,055529	

Table. 4. t-test: low workload

We verify that under low workload alerting was not significant, however under high workload the t-test revealed that the SAGAT scores without alerts were higher than with alerts, with a confidence level of 95%.
Regarding the exit questionnaire, the majority of the participants answered that the alerts system had a positive influence in their performances

	With Alerts	*Without Alerts*
Mean	0,584286	0,638571
Variance	0,019749	0,033813
Occurrences	14	14
Variance group	0,026781	
Hypothesis	0	
DF	26	
Stat t	-0,87764	
P(T<=t) one-sided	0,194087	
t critical one-sided	1,705618	
P(T<=t) two-sided	0,388175	
t critical two-sided	2,055529	

Table. 5. t-test: high workload

DISCUSSION

With a confidence interval of 95%, the results indicated that alerts negatively affected the SA of the group of participants as a whole.

Analyzing the two scenarios the results indicated a not significant difference in SAGAT performances. However the SA differences as function of the workload were noticeable. In fact, the results indicated that the high difficulty condition generated significantly higher SAGAT scores when the alerts were disabled. This result should not be necessarily interpreted as providing an advantage for C2 systems with no alert conditions, as alerts are important in bringing critical tactical situations to the attention of operator and users of networked C2 systems, however, attention must be given to the relationship between workload and the agility to enhance SA. In the current experiment, task difficulty was operationally defined in terms of the frequency of events occurrence presented to the participants via the display.We found that perceived workload increased as task difficulty was intensified. Workload also had an affect on SA, as participants had greater SA scores at the low difficulty level when alerts were enabled.

The reason why alerts diminish SA can be related with the way the alerts were shown and the interaction of the human with the computer.

Taken together, these findings underpins the connection between SA and mental workload. Both SA and mental workload require the same cognitive resources (attention), so that increased mental workload may reduce the individual ability to maintain SA [4].

We must also take in consideration the average age of the participants (37 years) and their inexperience in the use of the system “C2 em Combate”. Additionally, all had military careers with low emphasys on knowledge of the subjects which the questions of the SAGAT questionnaire approached, namely infantry military operations.

CONCLUSION

The results of the experiments reported herein suggest that an automated alerting systems, as IAAS, can diminish the SA even under low levels of workload. In fact, it was shown that IAAS had negative effects on SA at several levels of workload.

In contrast to what would be expected from previous results [1], we argue that the alerts system diminishes the SA of the operators, mainly under high mental workload conditions.

We can raise two causes that contributed to this conclusion. The first one is the human-computer interaction itself. Alerts sometimes confused situation following, and shifted the operator attention.Once the alert was issued, the operator concentrated in that event and temporarily lost a general vision, mainly when under high workload.

The second cause is related to the profile of the operators that took part in the experiment. Those were military personnel with many years of experience, experts in specific functions and procedures that never considered decision making procedures such as the ones demanded by the experiment. Interestingly, the majority of them reported that the alerts system influenced positively their performances, even though the experiments showed otherwise

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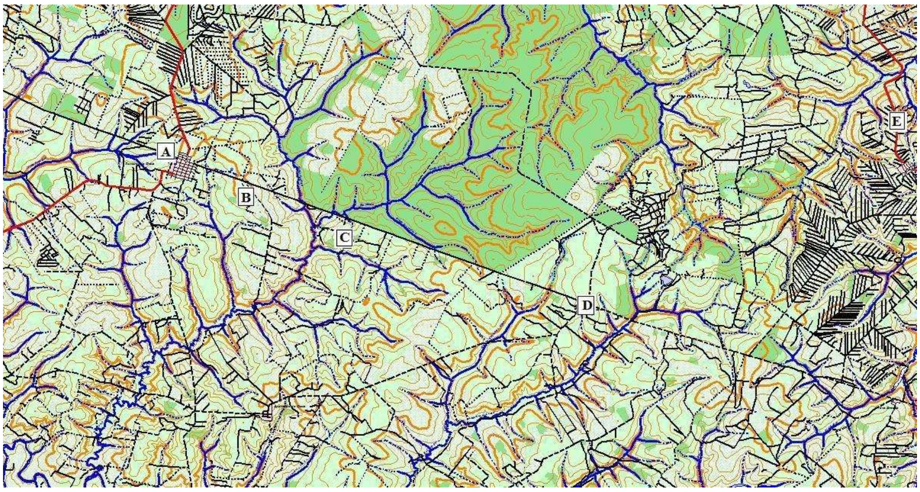
Appendix A

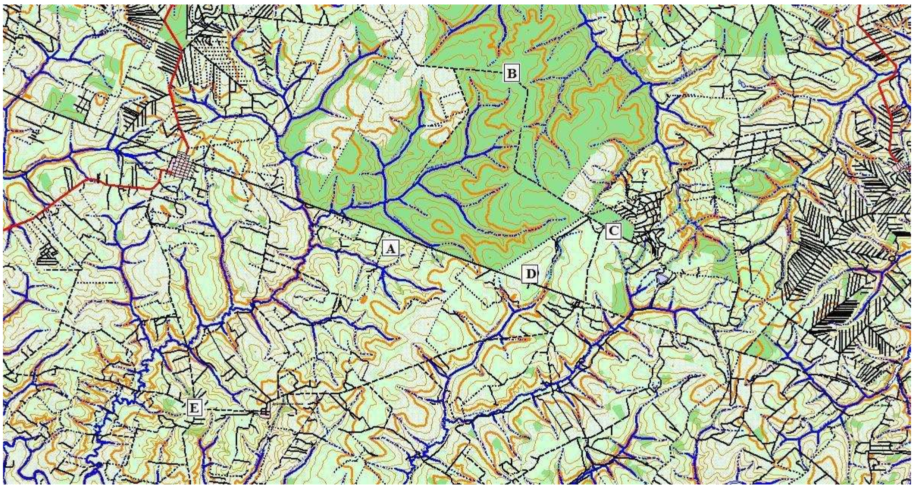
Example SAGAT Questionnaire from Experiment

1. What is the localization of the 51 Bda Inf Mtz?



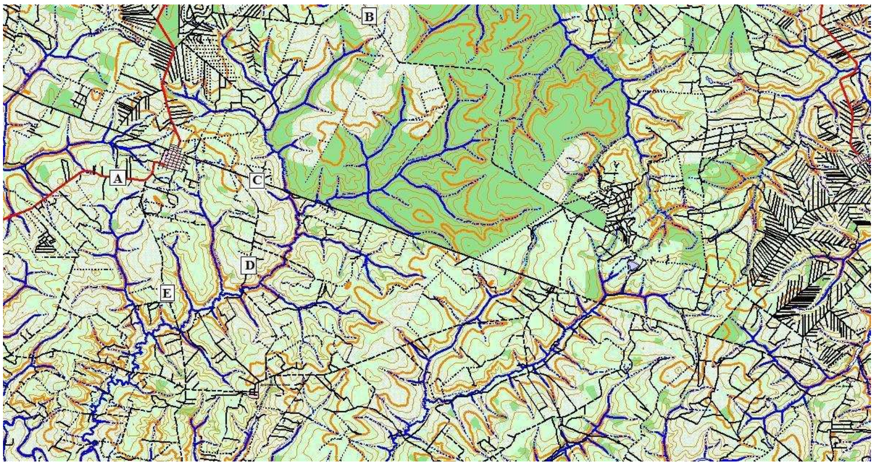
(A) (B) (C) (D) (E) (None)

2. Which subordinated units are present in the first step?



(A) (B) (C) (D) (E) (None)

3. Which enemy troops are next to your Unit?

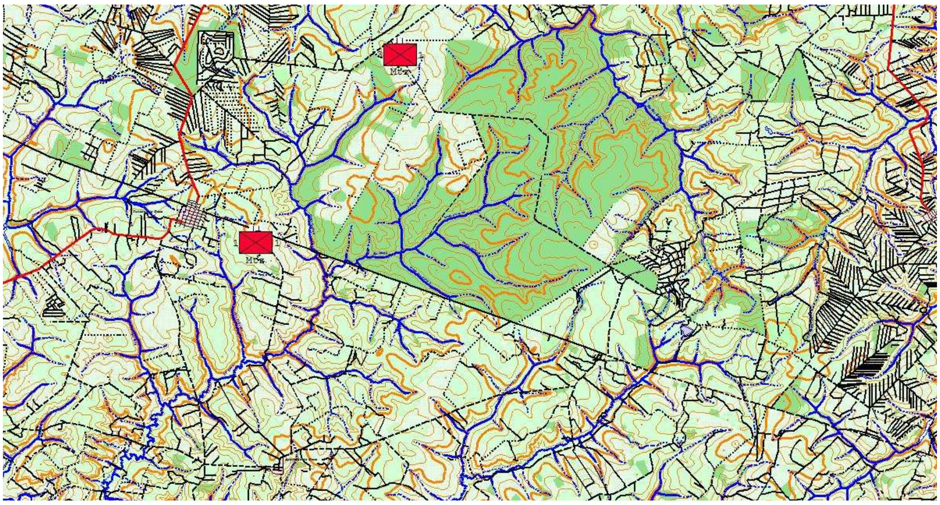


(A) (B) (C) (D) (E) (None)

4. How many progression axes are leased in the map?

0 1 2 3 4 5 6 7+

5. It sketches the progression axes for the enemy troops located?



6. Which are the enemy units value?

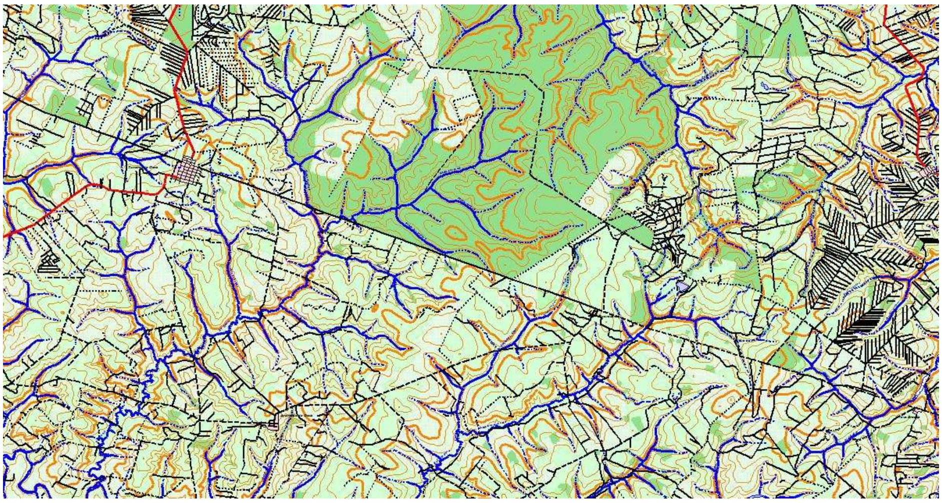
Squad Company Battalion Brigade Division

7. What is your mission?
a. To destroy enemy troops.
b. To fix enemy troops.
c. To defend an area.
d. Recognition.
e. None the previous ones.

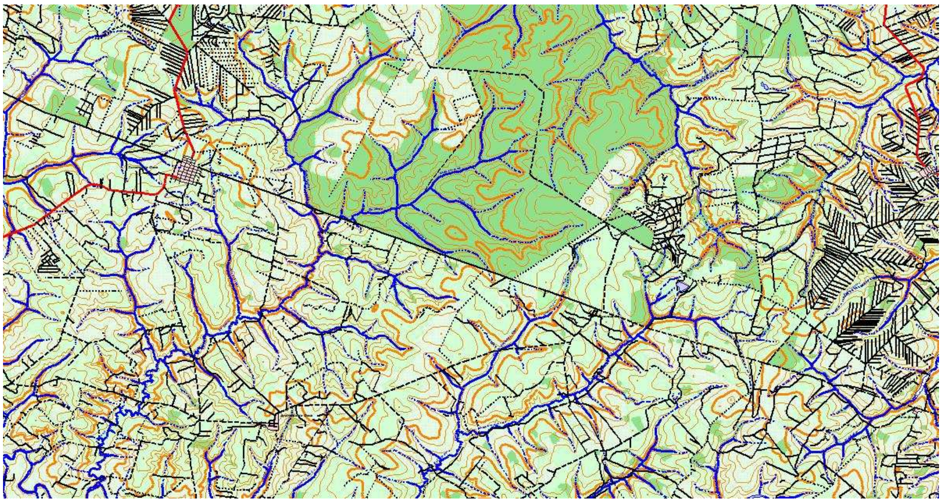
8. Which subordinated unit is more apt to carry out the main attack?
a. 51 Esqd C Mec
b. 411 BIB
c. 511 BIMtz
d. 512 BIMtz
e. 513 BIS

9. What are the movements foreseen by the enemy?
a. Retraction.
b. Frontal Attack.
c. Penetration.
d. Envolvement.
e. None.

10. Mark in the map the foreseen direction of attack by the enemy in case it takes the initiative.



11. Indicate one potential route of escape in the map.



12. Describe two risks for the maneuvre.

a.

b.