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IMPROVING THE COMMANDERS' SPEED AND AGILITY IN DECISION-MAKING

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Abstract:

In the research project "Military Decision Support Tools" we studied the support of decision making in highly dynamic situations in Crises Response Operations (CRO). Two types of decision support tool concepts were developed and tested: a Simulation Tool for current-future operational development (CFSim) and a Critical Thinking Tool (CTT). The CFSim addresses the complexity of multiple relationships of (military) agents and behavioral projection in the near future. The CTT addresses the problem of tunnel vision in appreciating new, deviant information.

To test the military applicability of our decision concepts we set up an experiment with four command teams (size four) from the RNLA operation training centre. The CFSim concept demonstrator was valued as positive in that it provided direct insight into the strong and weak aspects of potential CoAs. Participants agreed that the underlying simulation model should also include non-kinetic actions and effects typical for CROs. Integration of the concepts in existing operational C2 tools was seen as critical for acceptance. Overall, participants rated the application of the CTT as slightly positive. They were positive on the effectiveness, usefulness and added value of the tool, but they were not positive on its usefulness for speeding up the process.

1 Introduction

Military decision making is defined as the process of choosing an informed response to an operational problem or situation. The process can be extensive, comprising diagnosing the situation, additional data collection, Courses of Action (CoAs) generation, evaluation, and selection of options. The complexity of decision making depends on many factors including the fuzziness of the problem, the dynamics of the operational development, the reliability and volume of available data and its time horizon. Additional factors that have an impact on decision making are the ambiguity and scope of possible options and the tradeoffs, the stakes and tradeoffs involved in the eventual response option, the number of parties involved, and the experience of the participants and decision makers.

With such a complex process an all encompassing support concept is unlikely. Moreover, in practice people develop strategies and shortcuts to deal with these complexities ('naturalistic decision making'; Klein, 1997) and without understanding practice any support concept will fail. Andriole (1989) concluded from a state of the art review that decision support tools are most successful when targeted at well-bounded structured problems, and are less successful when targeted at unstructured ill-defined problems. Essens et al. (1995) found in a survey among developers of command and control decision support systems that few were actually fielded, only one of the twenty-six responses related to a deployed tactical aid. In a recent, informal, in-house assessment of our support tool successes a similar result was found. Essens et al also report that the survey and interviews indicated that current development practices for C2 decision aids are inadequate and that they can be improved by integrating techniques to deal with human factors and cognition.

In general, all tools that support decision making are labeled decision aids or support systems and no distinction is made between tools that support the acceleration of simple but time consuming processes and tools that support overcoming cognitive complexities. In the research project "Military Decision Support Tools"[1] we focused on two specific cognitive complexities in decision making: the complexity of multiple relationships of (military) agents and behavioural projection in the near future (the current-future simulation tool - CFSim) and the problem of tunnel vision in appreciating new, deviant information (the Critical Thinking Tool - CTT). We study the support of overcoming these issues in a (re)planning and decision making task at battalion level in fast changing critical situations in Crisis Response Operations (CROs). The hypothesis was that these support concepts would result in qualitatively better decision making and less erroneous behaviors, and thus improving the commander's speed in achieving effective decision making.

It is not the objective of our research however, to develop a decision support system that will ultimately assume the human commander's decision making responsibility. The levels of decision support have been categorized by Sheridan (1992):

1 no assistance, human action only
2 computer offers alternatives and
3 narrows selections to a few, or
4 suggests one, and
5 executes if approved, or
6 allows human veto for limited time, or
7 executes automatically and informs human, or
8 informs after execution only if asked, or

[1] The project was carried out as part of the V203 research programme on 'De toekomstige commandopost in een network centric omgeving" (The future Commandpost in a network centric environment).

9 informs after execution if computer decides to, or
10 the computer decides and ignores human

Level 1 has no Decision support, the human operator is in control. Level 6 is a 'last chance' option for 'critical threats' (e.g air-defence systems like Patriot or Goalkeeper).
The levels 7-10 in fact takes human 'out of the Loop' and are deemed not to be acceptable at this time. Levels 2-6 place final responsibility and decisions with the commander. These support levels are our objective.

Our approach was to develop two concepts, CFSim and CTT, build concept demonstrators and test/evaluate them with potential military users as a first step in developing successful decision support tools. First we discuss the decision making process in more detail, subsequently the two support concepts are described. Section 4 describes the experiment and the results. The final sections present conclusions and the plans for further development of decision support concepts.

2 Decision making and Command & Control

Independent of how it is organized, Command & Control can be described in terms of information acquisition (Observe), interpretation (Orient), decision making (Decide) and action completion (Act). This process is commonly known as the 'Observe – Orient – Decide – Act' - loop (OODA-loop, see inner circle of Figure 2-1).

Although the OODA-loop is a simplified representation of a decision process, it is a useful model to roughly indicate critical phases in this process. We will therefore use the OODA-loop as a base to indicate how our two support concepts should increase the quality and speed of decision making. One of the simplifications in the OODA-loop can be found in the fact that a decision making process is represented as a linear process. However, in practice several iterations may take place between the four phases. We have added these iterations to the OODA-loop as distinct concepts. In this manner the practice of decision making, including its cognitive complexity is more adequately represented. It is this cognitive complexity that our support concepts should help to overcome. Figure 2-1 visualizes the possible iterations that may find place between each of the decision phases. Each iteration is briefly described below and section 3 describes how our support concepts are assumed to interact with these iterations.

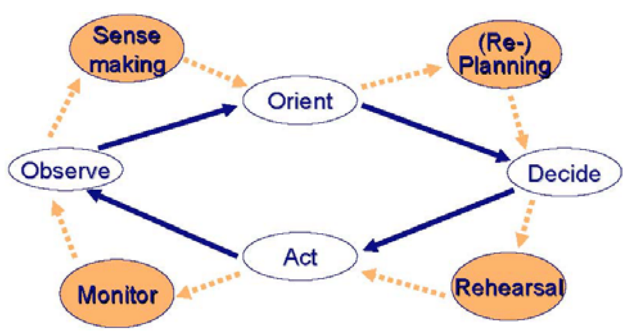

Figure 2-1 C2 Support in the OODA-loop

Sensemaking
In building an adequate interpretation of information (*Orient*) one may conclude that more information would increase its adequacy or that crucial information is lacking for it to be useful. As a consequence one may decide to search for extra information (*Observe*) before making a decision. A cognitive complexity here is that it is almost impossible to be sure that 1) all relevant information is collected and 2) crucial information is not overlooked. In addition, although it is relevant to develop an adequate interpretation of the 'current situation' (also known as 'Current'), it is even more important to being

able to adequately extrapolate from this situation into the near future. In other words, it is critical to develop clear awareness of situational *developments* and an adequate interpretation of the consequences of these developments. However, on a *static* display of the Current it is difficult to represent these developments.

(Re)Planning
In the *Orient* phase Situation Awareness (SA) is built. Based on this SA several possible CoAs are developed in order to eventually decide on the execution of one of them (*Decide*). However, in developing these CoAs more insight is gained into details of the situation at hand, which may lead to different or refined interpretations of the situation. In this manner the quality of the SA increases and may, in turn, inspire the development of different or improved CoAs.

Rehearsal
Before a certain CoA actually is executed (*Act)*, it is preferable to rehearse it. Several options are available for mission rehearsal: one may mentally simulate it, or use maps and drawings to simulate the operation. One may simulate the operation using miniatures (sand box), or execute it for real outside of the operational area, etcetera. These rehearsals may lead to new insights and as a consequence result in the necessity to review decisions made and choose a new CoA (*Decide*). The more realistic a rehearsal and the more factors are taken into account, the more likely it is that deficiencies of the plan are revealed. Rehearsals will allow the participants to better identify critical factors for success or failure. However extensive rehearsals take much time and thus have to be limited. It is important to find a balance between the relevance of a realistic rehearsal and the necessity to increase the speed of the decision making process.

Monitor
In this iteration the execution of the operation, the Current, is monitored (*Observe*). In monitoring the Current and comparing it to the original CoA (Plan) one can check whether the execution works out as intended. A cognitive complexity here is that it is hard to adequately evaluate (minor) differences between Plan and Current. These differences always occur and indicate that reality (slightly) deviates from plan, as always. These differences do not need to be an indication of a catastrophic mismatch of plan and reality. However, the differences may also indicate that the plan executed is not suitable (anymore), it may for example be based on assumptions that now appear to be wrong. In the latter case, differences between Plan and Current indicate possible severe consequences for the outcome of the operation and require a review of how to proceed in the operation (*Act*).

3 Decision making Support Concepts and Tools

This section discusses the two decision support concepts that were tested in our experiments. It also presents the tools and systems that were available to test these concepts. In each area we combine cognitive support concepts and computer-based simulation capabilities. The cognitive support concepts find their basis in characteristics of perceptual and mental processes, as well as of team, group and organisational processes. The computer-based simulation capabilities are based on well-developed wargaming techniques.

3.1 Current-Future Simulation Tool Concept

The first concept that was tested in this study is the Current-Future Simulation tool of Operational Development (CFSim). We have used the Command and Staff Trainer 'CaSTor' for our experiments. CaSTor is the new staff training tool in the Royal Netherlands Army (RNLA) .In our experimental set-up CaSToR simulates the development of operational situations. The CFSim is expected to support the quick analysis and review of possible tactical responses to changing situations, in particular in the space-time development.

Another functionality of the CFSim that is demonstrated in this study is to ‘go back in time’ and see how the Current situation has developed. The assumption is that ‘knowing where you come from’ helps to predict ‘where you go to’ in the near future (see also Weick and Sutcliffe, 2001). These two functionalities are provided in a so-called ‘replay-preview’ tool. The CFSim concept demonstrator is connected to the Integrated Staff Information System (ISIS), which is the RNLA’s C2 system.

The CFSim concept demonstrator tool as developed here is expected to support the military decision making process in four manners. Firstly, it may support the Sensemaking process for it helps to build and validate Situational Awareness (SA), as explained above. It secondly may support both the processes of (Re)Planning and Rehearsal in the same way: when a certain CoA is developed or chosen it may be ‘played’ using the simulation tool in order to be evaluated. In this way the support concept for (Re)Planning focuses on the process of quickly re-planning and projecting multiple relationships of (military) agents in the near future. The simulated CoA may reveal aspects that had been overlooked previously, or that need further refinement. Thirdly, it is possible to quickly and easily compare two plans on factors such as (predicted) duration or attrition. Fourthly, the CFSim can support the monitoring process by visualizing the chosen CoA while another program visualizes the Current activity as it develops. Visualization of both Current activity and Plan in parallel may support evaluation and interpretation of differences between the two.

3.2 Current-Future Simulation system

The RNLA’s Command and Staff Trainer ‘CaSTor’ is a detailed constructive combat simulation model that takes into account manoeuvre, fire support, combat engineering, air defence, air support, combat service support operations and amphibious operations. The model is capable of simulating ground operations at battalion, brigade and division levels. CaSTor can represent entities on a platform (e.g. vehicle) and aggregate (e.g. platoon, company) level. CaSTor will be used by the RNLA as the new exercise driver for Command Post Exercises (CPX). CaSTor and its predecessor KIBOWI have been developed by TNO. KIBOWI has been used by the RNLA for many years and is also in use by Belgian brigades and the Bulgarian army. Primary training audiences are typically staffs at battalion, brigade, and division level.

Obviously, staff training includes the use of ISIS, the RNLA operational C2 tool. ISIS will provide the COP and ultimately transform into an integrated C2 environment for planning and real-time control. CaSTor is a High Level Architecture (HLA) compliant simulation. HLA is the accepted international standard for reuse and interoperation of simulations. HLA is based on the very premise that no single simulation can satisfy the requirements of all uses and users. The intent of HLA is to provide a structure that will support reuse of simulation components and ultimately reduce the cost and time required to create a synthetic environment. TNO has developed an interface (Gateway) to ISIS based on this HLA simulation interface. As a first demonstration of interoperability between C2 systems and simulations, the CaSTor simulation system was coupled with ISIS (Huiskamp, Kwaijtaal, Fiebelkorn, 2003). The intention was to provide situational awareness for trainees as they used their operational ISIS tools. CaSTor drives the scenario in the ISIS-CaSTor federation. The operational context simulated by CaSTor consists of formations of own and hostile ground forces. These units provide a dynamic and representative environment for the ISIS operations. During a scenario run, each CaSTor unit executes a predefined list of orders. This largely eliminates the need for role-player interaction during execution and ensures repeatability of the scenario.

CaSToR has many elements of a traditional *kinetic* war game. The term kinetic typically means attrition based, symmetrical warfare simulation with linear cause and effect relations. In contrast, non-kinetic models offer more complex relationships including effects of e.g. psy-ops and effects of support offered to the population. It is clear that given the current type of operation that the RNLA is involved in, the CFSim concept will have to be extended with support for non-kinetic effects to become more useful.

3.3 Critical Thinking Tool concept

The second concept that was testing in this study is the Critical Thinking Tool (CTT). Cohen, Freeman, and Wolf (1996) introduced the concept of Critical Thinking to tackle the issues of tunnel vision and information bias. They applied this concept only to support training and not (yet) to support actual work processes. We applied their concept to develop a concept for overcoming tunnel vision and information bias in operational decision making processes. We refer to our concept as the CTT because it help users to keep track of options during the decision making process. This is achieved by using colors to encode how evidence supports (or does not support) a hypothesis (Schraagen, Eikelboom, van Dongen and te Brake, 2005). When ambiguous information about events becomes available, decision makers are often tempted to quickly choose a particular explanation for the observed or reported events. As a consequence of the cognitive tunnel bias, subsequent information that contradicts the initial story may easily be discarded or misinterpreted.

We think that by visualizing the argument structure, that is, the relation between evidence and hypotheses in the interface of the tool, we can reduce these problems. This way of working has the advantage of off-loading memory, and enabling the user to think freely of other hypotheses. In this manner, the CTT also supports making implicit assumptions explicit. Making implicit assumptions more explicit supports people to self-critique ideas, to request critiquing assistance from another person or computer and it helps to hand over a task and review a situation and learn from it. We assume that the CTT concept results in a qualitative better decision making process, especially in situations where information is ambiguous and incomplete.

In our study the CTT concept is tested and applied in the military decision process. We focused on a test of the added value of the CTT in two phases: Sensemaking and Monitoring. Firstly, Sensemaking: we assume that the CTT concept supports overcoming the tunnel vision bias as it supports a structural critical review of all incoming information. The support concept for Sensemaking focuses on the process of matching new information with existing assumptions and perceptions of the situation or, stated the other way around, critiquing existing perceptions or assumptions that are the basis of developed plans.

The CTT further supports the command team by immediately and explicitly analyzing incoming messages and other information on whether these are in support of or in conflict with operational assumptions of pre-planned CoAs. If information is supportive then the user chooses green to code it, if it does not support the hypothesis the user chooses red. There is also the option that information is not informative, in order to prevent this information as being interpreted as supportive or not supportive is should be colored yellow. In this manner users try to fit a piece of information into a coherent story. The trick is that they do not try *to build* a story based upon the incoming information, but that they try to *support (or falsify)* a story (hypothesis) based upon incoming information (see Figure 3-1).

	A	B	C	D
1	**Kritische factoren**	**CoA1, vertrek via Deventer**	**CoA2, vertrek via Olst**	**CoA3, vertrek via Zwolle**
14	Op de route N337 in Deventer zijn enkele snelheidsbeperkende maatregelen			
15	route (N337) van Windesheim naar Zwolle geen problemen geeft.			
16	Bericht ik dat de route door Deventer obstakelvrij is. Enkel alleen voorgenomen route (Henri Dunantlaan) beschikbaar, beperkte uitwijkmogelijkheden in verband met smalle straatjes en vele bochten in de omliggende wegen			
	Het verzamelgebied is in orde bevonden. Terrein is OK			

Colour		Meaning
Green		Supportive
Lime		Supportive, weaker
Orange		Slight undermining
Red		Undermining
Yellow		Neutral
Empty		Not yet coded

Figure 3-1. Example of filled-in Critical Thinking Tool and the color encoding used.

4 Experiment

To test the military applicability of our tools, we set up an evaluation experiment with four command teams (size four) from the Dutch military staff. Each team consisted of two cells (size two), a Current cell and a Plan cell. The CFSim concept tested in the experiment supported the quick analysis and review of possible tactical responses to changing situations, in particular in the space-time development. The CTT supported the command team to immediately and explicitly analyze incoming messages and other information on whether these are in support of or in conflict with operational assumptions of pre-planned CoAs.

4.1 Design

In total four teams participated in this experiment: on two separate days two teams executed our experimental program in parallel. Every team was instructed to work with the simulation tool, especially the Planning cells of all teams. Every team received the same briefing on the current mission objectives and the current situation. The CFSim was tested by providing all teams with the simulation tool and ask the participants to compare using the tool with their current working methods.

The test the added value of the CTT it was only provided to two of the four teams and these teams received training on using the CTT in advance. The other two teams were not provided with the tool. The assumption was that the teams using the CTT would much earlier decide to reject the initially preferred CoA and change to an alternative.

Scenario

Each team participated in the same scenario. We developed the scenario ourselves and it is freely based on situations in CROs. The teams were instructed that they participated in the operation International Stabilisation Force Eastern Netherlands (ISFEN). They formed the staff of the Belgian Task Force that had the command in Regional Command North. Their Area of Operations was placed in the eastern part of the Netherlands (see Figure 4-1). They had been active in this area for 6 months now and were about to transfer command, redeploy and leave the area. Three CoAs were developed for their redeployment and their commander preferred the shortest route: a redeployment via *Deventer*. The two other options were leaving the area via *Zwolle* (in the north), or via *Olst* (between Deventer en Zwolle). For this last CoA to be executed it was necessary to cross a wide river.

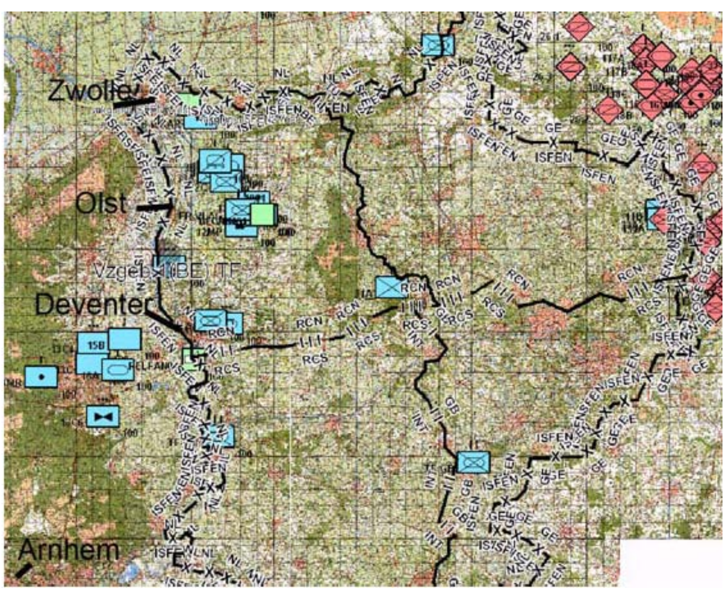

Figure 4-1. Map of the Area of Operations, the participants are place in the upper left corner area

At the start of the experiment the participants had to wait for further instructions to actually start the redeployment. Meanwhile, they had to monitor the operational area, for it was expected that several sections of the population may obstruct the taskforce leaving the area.

The scenario that was used had a simulated duration of about 8 hours and a wall-clock runtime of about 105 minutes (i.e. the speedup factor was about 4 times). The first 20 minutes were used to get the users up and running. The next hour the amount of messages that was sent to the teams increased. It was intended that in this manner the teams would experience increased time pressure and could not easily gain an accurate overview of the situation.

Task and instructions
After the teams had received the information described above, the experiment started. During the experiment they received all kinds of messages informing about developments in the operational area. The Current cell had the assignment to keep track of all incoming information. Team members in this cell had to monitor the operational area, for it was expected that several sections of the population might obstruct the taskforce leaving the area. If events in the area indeed indicated that such developments took place, they had to advise their commander to re-plan and recommend another CoA. The second task was assigned to the Planning cell. Halfway through the experiment the team was instructed that hostile forces had approached the area from the east and that it had to plan for possible support at the eastern border. Both cells within the teams were instructed to keep each other up-to-date while performing their tasks.

Technical set-up
The CFSim and the CTT were still in the concept phase during the experiment, therefore first demonstrators of both tools were applied. The goal of the experiment was to determine whether their functionality was useful, therefore it was decided to work in a 'Wizard of Oz' construction. Figure 4-2 shows the technical set-up during the experiment. Each team-member had a PC loaded with ISIS, CTT, CaSTor (CoA B1) and CaSToR (CoA B2). The Current could be viewed via ISIS, and it also showed the information messages that became available. The Current and information messages were sent from the 'kitchen' to the individual PCs and one was connected to a beamer, so the four team members could 'share' one screen by viewing its (enlarged) projection on the wall.

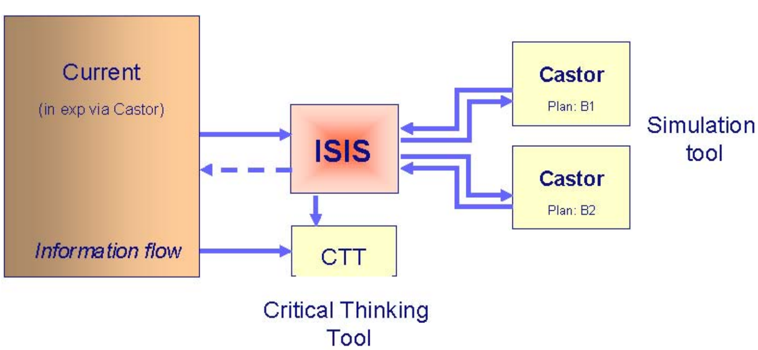

Figure 4-2. Technical set-up during experiment

Measurements and Monitoring
Several measurement techniques were applied during the experiment in order to test the usefulness and level of support of our concepts. In advance of the experiment a general questionnaire addressing personal aspects such as age, range, military experience and experience with several computer applications was conducted. Each team had one observer monitoring the working methods of the teams. In addition to the observer reports, we also had a camera which recorded the team for backup purposes and a logging tool was used that captured all four PC screens of each team at regular intervals.

After the experiment the participants were asked to complete two Tool Questionnaires. These assessed the participants opinions about how CFSim and CTT fit into their work process and what they felt would be the perceived benefits of implementing these tools. In a final session we had a discussion with the respondents about the potential usefulness of each of the tools.

4.2 Tools

CFSim

In this experiment the CFsim supported two (Re)Planning tasks. The first task was assigned to the Current cell within the teams, they had to keep track of all incoming information and keep their Operational Picture accurate and up-to-date. By visualizing developments in the operational area via the CFSim, it was demonstrated how such a visualization may support gaining a Common Operational Picture and thus supports Sensemaking and Replanning.

The Planning cell received a planning task halfway through the experiment. Two possible CoAs for this assignment were developed in advance by the experimenters and could be viewed using the CFSim. The cell was instructed to evaluate these two CoAs and the implications for their own and enemy units. Based on the two simulations the teams had to decide which tactic was most promising given a two-fold assignment: 1) to delay the enemy units for approximately 10 hours in a given area and 2) to maximize the loss of enemy units. The goal was to demonstrate how a simulation tool can support a quick review and evaluation of two different CoAs (Replanning).

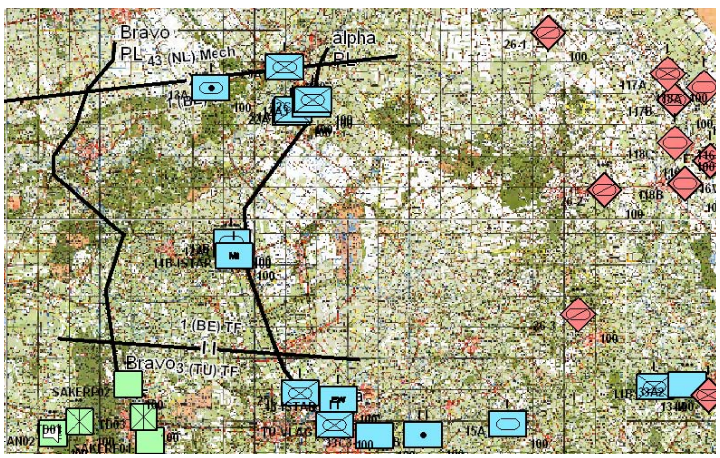

Figure 4-3. Example of the ISIS map showing the approach of hostile units (red)

Critical Thinking Tool

In this experiment the CTT supports Sensemaking and (Re)Planning.

The CTT supports an effective interpretation of the world with respect to one’s own goals and plans. In this experiment the main focus of the CTT concept was the immediate encoding of incoming information. In this manner the teams would immediately and explicitly process this information. Figure 3-1 shows that each information element is assessed for the three CoAs for redeployment and color encoded as a result of this assessment.

5 Results

5.1 Users – general

All participants were serving in the RNLA for a long time (on average 27 years and 8 months). Half the group participated in one CRO, four people in two CROs and two people in three missions. Two participants participated in even more missions: 6 respectively 7. Only two participants claim to have no significant practical experience with the operational decision process (OBP in Dutch). However, because of their job they have theoretical knowledge of this process.

The group was experienced using a computer, approximately 25 hours per week (work and free time). They rated themselves hardly-experienced users of ISIS, a 2 on a scale from 1 (not experienced) to 5 (very experienced). When asked whether they had any experience with computer simulations, seven answered *no*, and eight answered *yes*. Their experience ranged from users of Kibowi to other domain related games and driving simulators.

From these figures we can conclude that the experimental groups in general were accustomed to use computers. Relevant experience with simulation and simulation-related games was however mixed.

5.2 Results of CFSim

Results of Tool Questionnaire - CFSim

In this questionnaire participants were instructed to value the functionality and not the tool as such (e.g. user friendliness of the application). However, when participants added comments some of these concerned the presented tool. The next figure shows the answers to the seven statements on the use of the simulation functionality. The answer-scale ranged from 1 (not at all agree) to 5 (very much agree). The net number evaluated was 11 because 3 participants did not work with the simulation tool while one scored all 5s and a second scored all 1s without any comments to explain their scores.

Figure 5-1 below shows that the questionnaire average scores were positive about the functionality of CFSim. The use of CFSim was considered to have a positive effect on the outcome of the participants' work. According to the participants the use of a simulation leads to better analysis of the situation and of possible actions. Many comments related to the issue of using kinetic 'war gaming' modeling as a base for the simulation. Participants were of the opinion that this resulted in a less useful simulation tool, especially because in current missions many non-kinetic aspects are of importance. Other comments that were made concerned:

- the necessity to educate (potential) users,
- the further development of the tool, including an extension of the parameters,
- the potential of using the simulation tool as a training tool,
- the interface: the look and feel of current commercial games was considered very cool and nice, military tools should be comparable with these tools

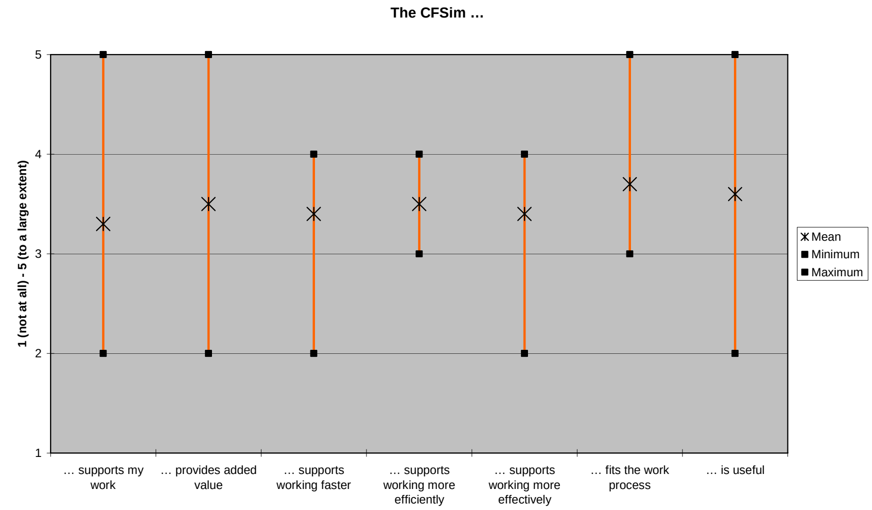

Figure 5-1 Scores on CFSim Tool Questionnaire (11 participants)

Briefing

The text below is a summary of the discussion that was held with the participants.

Uses of Simulation
Several situations were suggested in which a simulation based on non-kinetic models might be useful. Examples are training and mission rehearsal, this could be relevant in (3D) urban environments. Special non-kinetic elements that are missing in most models are e.g. psy-ops effectiveness and support to and from the population. An example of a non military use could be a water flow simulation in case the RNLA is asked to aid in flooding emergencies.

Input for simulations:
The input for the simulation consists of the current situation including all parameters describing own and enemy parameters (e.g. strength and aggressiveness). These parameters include estimates about unobserved enemy forces, as well as parameters describing other parties such as the population (culture, religion, attitude towards forces, etc.). Added to the current situation is information present in ISIS on the terrain and predictions on e.g. the weather. The new plan is developed by specifying a set of orders to be carried out by th(for own and enemy forces and other parties) and possibly changes in parameters.

Respondents agreed it should be easy for the user to set and play with the input parameters for the simulation, e.g. properties and number of own and enemy units. They added that it may be desirable to have the simulation stop at specific points in time or at the occurrence of specific conditions. At these points the user is asked to specify what the units should do next. In this way a plan tree is created consisting of many branches coming from sub-decisions.

Output of simulations:
In general the input parameters are chosen with some amount of subjectivity. The consequence is that the output will also have some subjectivity in it. It is expected, however, that the output of the simulation will be more objective than when making plans without this tool. The output can be used for several products.

General conclusions

Overall the participants think that the simulation functionality is useful for the (RE)Planning process. It provides support for gaining insight into the strong and weak sides of a CoA. However, the group made a number of firm statements. First, about the validity of the underlying model: that should also support non-kinetic factors, otherwise it is not useful for the current type of missions. Second, the interface should be interactive and visualize the results of the analysis in a user-friendly way. Third, the participants mentioned the necessity of integrating the simulation tool with existing C2 tools.

5.3 Results of Critical Thinking

Results of Tool Questionnaire - CTT

In this questionnaire participants were instructed to value the functionality and not the tool as such. However, as with the CFSim concept demonstrator tool case, some of the comments mainly concerned the presented tool. The next figure shows the answers to the seven statements on the use of the Critical Thinking functionality. The answer-scale ranged from 1 (not at all agree) to 5 (very much agree). Only eight participants, two teams, worked with the CTT during the experiment. One of them did not fill out the questionnaire, so the results are based on the answers of 7 participants.

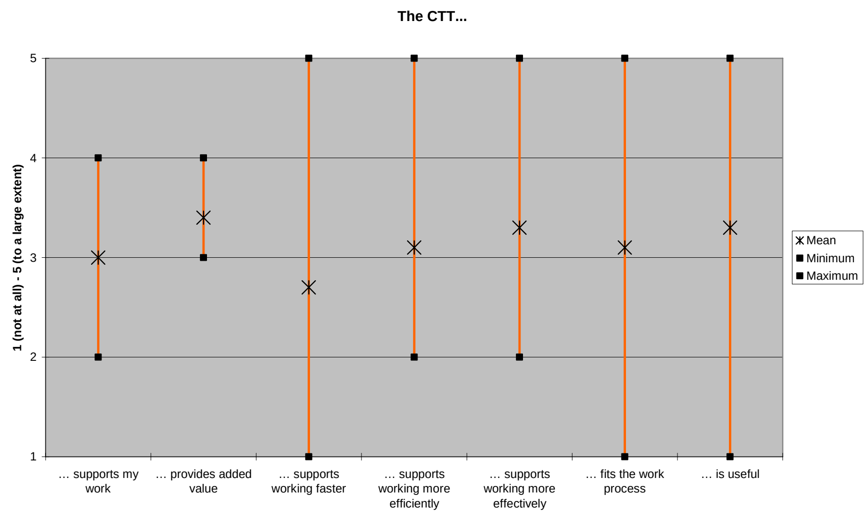

Figure 5-2 Scores on Critical Thinking Tool Questionnaire (7 participants)

Overall participants rated the use of the Critical Thinking coding as neutral to slightly positive. The fourth row shows that using the system does not speed up the decision process according to the respondents. However, the effect on the outcome of the work process is rated as being more efficient and effective. The main comment of all users was that this way of coding should be incorporated into existing tools, and colors used should correspond with color schemes currently used on for example military maps.

The experiment was set-up to measure the effect of the use of the Critical Thinking method by providing only one team with the tool. We collected observations from the teams to be able to tell the difference between the two conditions. The assumption was that the teams using the CTT would much earlier reject the initially preferred CoA (CoA *Deventer)*. We had the intention to measure this effect by marking the moment in time the team decided to reject CoA *Deventer* and switch to another CoA. However, it proved hard to actually conduct this measurement at all, let alone comparing results between teams for several reasons:

On the first day the team without the CTT erroneously interpreted the operational assignment (plan for redeployment and meanwhile monitor the operational area) and thought they had started redeployment. As a consequence they did not monitor the applicability of the chosen CoA anymore. On the second day, the team using the CTT complained that CoA *Deventer* was too dangerous given the circumstances shortly after the experiment was started. However, when they were asked to write a recommendation to their commander, they wrote that CoA *Deventer* was still an option, although additional safety measures had to be taken. At a later moment, they explained to the observers they felt not entitled to advise the TaskForce to adopt another CoA than the initially intended one.

In all groups it was observed that individuals for themselves made the decision that CoA Deventer was not suitable anymore, however, they did not share this interpretation. Not with their team mates and not with observers.

Debriefing
The following text is a summary of the debriefing and discussion session at the end of the day.

Suitability:
One main condition mentioned during the discussion was that the CT method should only be used during complex missions and in small battalions. The method is also suitable to forward messages (including encoding) to other teams (same level, lower and higher level).

Pros and Cons:
Participants indicated that color encoding is done according to personal interpretations, which might be wrong. The positive side however is that by making these mental judgments explicit and visible, that others can correct or critique it. In this way the 'filled in CTT' may function as a sort of public external memory and as such can be consulted and reviewed by others. It may also be used in hindsight to derive lessons learned. All participants stressed that such a tool should not be introduced as a separate tool, but that it should be integrated with existing tools, such as the journal or logbook.

Negative aspects that came up during the discussion were that individual messages were interpreted in isolation. Participants argued that you need to place information into context for a worthwhile interpretation. And participants brought up the risk that users might 'stop thinking' and start 'counting colors' to make a decision. Especially under time pressure users might compare 8 'greens' with 1 'red' and overlook the importance of the single red field. Or overlook that 8 green information elements actually reflect one 'green fact'.

Meta-data:
There is much more meta-data that plays a role in interpreting information, for example certainty, importance, reliability of the source, confirmation, amount of messages on an incident, etc. This type of meta-data should be incorporated in the CT method.

Discussion
During the debriefing one participant mentioned the risk he perceived in coding information in isolation, namely message by message. That is a relevant comment. However, every message is evaluated in relation to a hypothesis and from that perspective *not* in isolation. In this manner the tool supports overcoming the bias of tunnel vision. The basic idea is that users commonly have a hypothesis or action in mind. The Critical Thinking method supports users to keep an open mind. It is not problematic to have a preferred hypothesis, as long as at least one alternative hypothesis is also taken into consideration. Especially when new information becomes available.

The main concern from the users was the time it takes to encode every individual piece of information. This is a big issue, especially when the tool should support Critical Thinking during a time-critical task. In addition, when the user develops a new hypothesis and has to go over the entire list to code the information for this new hypothesis it does not save time either.

General conclusions
The Critical Thinking method (color coding) adds useful elements to the decision making process. For it provides direct insight into the weaknesses and strengths of multiple CoAs. However, it takes a lot of time to work with it and the coding should definitely be integrated with a existing operational C2 tools, or a new tool that will enhance information management and processing while reducing the workload.

6 Conclusion and discussion

Summary of experiment
A commander needs quick insight into the implications of the developing situation and should be able to determine the value of actions more quickly. We have introduced two support concepts, CFSim and Critical Thinking, to support the commander during the decision making process. These two concepts were tested with potential military users as a first step in developing successful decision support tools. With this experiment the effects of support techniques on rapid decision making and re-planning were examined.

Every team in the experiment played a scenario during which two assignments were given, an operational assignment (Current cell) and a planning assignment (Planning cell). Members of the Current cell had to decide on the best CoA for redeployment, given the current situation. For two of the four teams the CTT was available to support the members with this operational assignment. The other teams had to work with traditional tools. The planning Cell had to develop a plan for delaying enemy units in a given area. CFSim concept demonstrator showed two possible CoAs to carry out this operation.

Summary of conclusions
Overall the participants think that the CFSim is useful for the (Re)Planning process. It provides support for gaining insight into the strong and weak sides of a CoA. However, the group made a number of firm statements. Firstly, about the validity of the underlying model: that should also be based on non-kinetic factors otherwise it is not useful for current missions. Secondly, the interface should be interactive and visualize the results of the analysis in a user-friendly way. Thirdly, the participants mentioned the necessity of integrating the simulation tool with existing C2 support tools.

The Critical Thinking method adds useful elements to the decision making process. For it provides direct insight into the weaknesses and strengths of several CoAs. However, it takes a lot of time to work with it and it should definitely be integrated with existing tools.

Discussion
At some point participants uttered statements about their work process that contradicted the known information or even each other. We think this is an indication of the fact that many different work practices exist in reality. It makes it more difficult to draw a general conclusion on their working situation, as apparently the culture of a battalion has a large impact on the way of working and the use of tools. More insight is needed and this fact needs to be taken into account for future work. A good way to manage these differences is to include different stakeholders in the development process.

The CFSim concept demonstrator that was used in the experiment was just a set of movies of prepared mission plans, and as such was non interactive and not coupled to ISIS. The used simulation model, CaSToR, is at this moment too difficult to use without extensive training. Also the existing coupling between CaSToR and ISIS is limited. It is not versatile enough for full control of the simulation via the ISIS interface.

The TNO vision on simulation based decision support is much broader than shown in the demonstrator, it also contains ideas on functionality and interface elements for the C2-system. An example of such a functionality is the ability of the user to specify the automatic generation of warnings when e.g. the concentration of red forces is higher than that of blue forces in a specified area. An example of an interface element is a time slider for both the display with the current situation and for all displays with simulation results for plans. The time slider for the current display should contain the real logged history, the current information and results from a continuously updated simulation taking the current situation and plan and already given orders into account. The simulation should be fully interactive and coupled to the C2-system to ensure all information is available and can be shared. The use of interoperability standards should provide mechanisms for loosely coupling of the various sub-systems. This means that the specific simulation used can easily be replaced by a different model. For example a fast attrition based model must be replaceable with more complex models for calculation of e.g. psychological effects. It is also possible to use non-military models for e.g. calculation of water heights during river floods. The use of standards should also prove to facilitate upgrading of sub-systems. The use of a multifunctional architecture for the coupling of C2 and simulation is currently being researched at TNO (Borgers, 2007).

A main disadvantage of the Critical Thinking method is the time it takes to code all the messages to reach a conclusion. The same disadvantage is valid when a new hypothesis or CoA is included and the user has to go through all the information again to code it for the new hypothesis. One can think of several solutions for these problems, but these lead more or less to the same problem: it has a negative effect on keeping the user in the loop and thus reduces his situation awareness. For example, if the user asks someone else to code the information, it still takes time and the other person is more 'in the loop' than the primary user. Another possible solution is to apply automatic coding, where the computer supports the user in coding the information. The main drawback of these solutions is again the out-of-the-loop problem. The user is no longer aware of the actual information and this might lead to the situation where the user makes a decision based on more green or red colors and not on understanding the situation. Automated encoding is a serious option to reduce time and workload, but given this risk it is not a very attractive option. Research is needed to investigate how computers can support information encoding and still keep the user in the loop so that informed decisions can be reached in a shorter time, with equal or more confidence as at this moment.

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