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Title:
Computer-based Critiquing Systems :
Cognitive Support Tools for the Estimate Process

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Computer-based Critiquing Systems: Cognitive Support Tools for the Estimate Process

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Abstract

The Canadian Forces Operational Planning Process is a methodical approach to analyzing a situation, bringing staff expertise to bear on the relevant factors, narrowing courses of action, obtaining the commander's approval, and developing the detailed annexes necessary to produce an executable plan. It is based on an Estimate Process that involves the elaboration of different Courses of Action following situation analysis and the selection of the most appropriate one for its subsequent planning.

Since military operations are evolving into a dynamic, complex and uncertain environment, the Estimate Process is often performed under high time pressure and stressful conditions. Under the influence of these factors, the human capacity of reasoning and judgment can be significantly reduced. In order to support the commander and his/her team in carrying out the Estimate Process, different types of computer-based decision-support systems can be proposed. This work is related to the investigation is computer-based critiquing capabilities.

This paper briefly presents the three stages of the Estimate Process (initiation stage, orientation stage and COA development stage) and identifies some of its elements that could benefit from being challenged. From that work, three categories of critiquing systems that could be developed for the Estimate Process are proposed. Finally, the critiquing systems that directly counteract cognitive biases are designated as cognitive support tools.

1 Introduction

The Canadian Forces Operational Planning Process (CFOPP) is a systematic approach to analyzing a situation, bringing staff expertise to bear on the relevant factors, narrowing Courses of Action, obtaining the commander's approval, and developing the detailed annexes necessary to produce an executable plan [1]. Adapted to the needs of the operations, it can be used with different time constraints for different levels of planning: strategic as well as operational and tactical. It is the process used to prepare plans and orders for CF operations [2].

The CFOPP is comprised of five main stages (Figure 1) with specific outputs [1]:

- The Initiation stage results in the activation of the planning staff, and the commander's guidelines about the kind of planning process to achieve.
- The Orientation stage results in the development of the commander's planning guidance. In this stage, the commander orients his/her staff in the determination of the nature of the problem and the confirmation of the results to be achieved.

- The Course of Action (COA) Development stage results in the production of the CONOPS that identifies the commander's line of action in order to accomplish his/her mission. It presents the COA that will be implemented.
- The Plan Development stage results in a set of orders based on the commander's decision to provide subordinate and supporting units with all of the necessary information to initiate planning or execution of operations.
- The Plan Review stage results in a regular review of the plan to evaluate its viability. The period used to review the plan depends on the evolution of the situation, the type of operation and the environment.

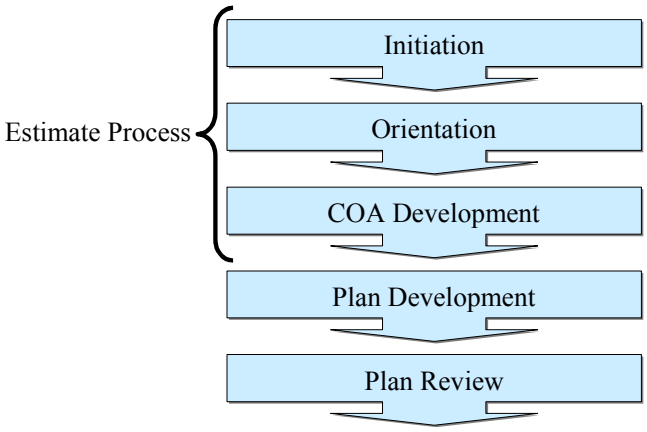

Figure 1. **CFOPP**

Since military operations are evolving into a dynamic, complex and uncertain environment, the CFOPP is often performed under high time pressure and stressful conditions. Under the influence of these factors, the human capacity of reasoning and judgment can be significantly reduced. Accordingly, different approaches have been proposed to improve the military command decision-making. One of them is to increase the role of critical thinking [3]. Critical thinking is "The ability to analyze, criticize, and advocate ideas; to reason inductively and deductively; and to reach factual or judgemental conclusions based on sound inferences drawn from unambiguous statements of knowledge of belief" [4]. Critical thinking motivates one to look for evidence that could potentially contradict what one believes and leads to evidence that potentially disconfirms one's mental model and necessitates adaptation of one's problem solving strategy [3]. In his work, Bryant concluded that critical thinking could enhance decision-making. Accordingly, considering decision-support systems that introduce some of the concepts associated with a critical thinking approach seems a good idea to improve the CFOPP.

This work focuses on the three first stages of the CFOPP, called the Estimate Process. Through the Estimate Process, the planning staff has to:

- Identify or clarify the goal to achieve;
- Understand the situation in which the decision has to be made;

- Identify (generate) the courses of action (the alternatives);
- Analyse them; and
- Make an enlightened choice based on the commander's own preferences.

In order to automate critical thinking concepts into this process, we need to determine aspects/elements of the Estimate Process that could benefit from being challenged (criticized). Only then, associated computer-based decision support systems could be identified.

Since these computer-based decision support systems should provide a cognitive support to human users, we need to conceive them to counteract the biases that result from limited cognitive resources. These biases have already been classified according to three different aspects by Wickens and al. [5]: Cue reception and integration; Hypothesis generation and selection; Plan generation and action choice.

Mostly related to working-memory limitations, human information processing biases in receiving and using cues are [5]:

- Attention to a limited number of cues: "People can use only a relatively small number of cues to develop a picture of the world";
- Cue primacy and anchoring: "Information processed early is often most influential, and will ultimately affect decision making";
- Inattention to later cues: "Cues occurring later in time of cues that change over time are often likely to be totally ignored";
- Cue salience: "Perceptually salient cues are more likely to capture attention and be given more weight (Endsley, 1995; Wickens & Hollands, 2000)";
- Overweighting of unreliable cues: "When integrating cues, people often simplify the process by treating all cues as if they are all equally valid and reliable".

Mostly related to long-term memory limitations, biases in hypothesis generation, evaluation and selection are [5]:

- Generation of a limited number of hypotheses: People consider only a small subset of possible hypotheses, and under time stress conditions, tends to limit themselves to only one;
- Availability heuristic: Hypotheses that have been considered recently or frequently will be retrieved more easily;
- Representativeness Heuristic: "Sometimes people diagnose a situation because the pattern of cues looks like or is representative of the prototypical example of this situation. This … can be biased when a perceived situation is slightly different from the prototypical example even though the pattern of cues is similar or representative";
- Overconfidence: "People are less likely to seek out for alternative hypotheses or to prepare for the circumstances that they may be wrong";

- Cognitive tunnelling: “When an hypothesis has been generated or chosen, people tend to underutilize subsequent cues”;
- Confirmation bias: “People tend to seek out only confirming information and not disconfirming information”.

Mostly related to basic memory processes, biases in action selection are [5]:

- Retrieve small number of actions: “People are limited in the number of possible action plans they can retrieve and keep in their working memory”;
- Availability heuristic for actions: People retrieve the most “available” action from their long-term memory. “The availability of items from memory is a function of recency, frequency, and how strongly they are associated with the hypothesis”;
- Availability of possible outcomes: People retrieve the most “available” outcomes;
- Framing bias: Decisions are affected by the way a decision is framed (presented).

Based on the Estimate Process elements/aspects that could benefit from being challenged and the human biases that need to be counteracted, different computer-based critiquing systems can be proposed as cognitive support tools. Accordingly, this paper briefly presents the three stages of the Estimate Process (initiation stage, orientation stage and COA development stage) and identifies some of its elements that could benefit from being challenged. From that work, three categories of critiquing systems that could be developed for the Estimate Process are proposed. Finally, critiquing systems that directly counteract the biases described by Wickens and al. are designated as cognitive support tools.

2 Initiation Stage

The *Initiation* stage commences when an initiating directive is received. This stage consists in activating the planning staff, gathering of planning tools (e.g. maps of the area of operations, own and higher headquarters’ standing operating procedures (SOPs), appropriate documents), production of staff guideline related to how to apply the planning process as well as the time available to achieve it. Essentially, the commander informs the team on how the process should be carried out.

At this point, one can question these aspects:

- The planning staff;
- The decision-making strategy;
- The planning tools.

2.1 The planning staff

A set of people having different expertise areas contributes to the accomplishment of the Estimate Process. Even if the different functions to be executed at the different stages are well identified, no formal procedures to execute them are defined [2]. Therefore, the planning staff employs intuitive strategies to execute these functions [2]. Based on their experience, background and capacity to retrieve relevant knowledge stored in their memory, they use the Estimate Process to guide them in order to provide their commander with a recommendation on the best COA to execute [6].

According to the social factors concepts described by Wickens and al. [5], the planning staff can be characterized as a team. They have noticed that most of the definitions of teams seem to center around the concepts of a common goal or output attained by multiple people working in an interdependent manner. These concepts are at the center of the planning staff during the execution of the Estimate Process. As mentioned previously, the expertise is distributed among the staff members. These people are from different military environments (air, maritime, land), have different specializations and contribute together to the process. It is expected that the quality of the result will be improved by the contribution of more than one individual. Effectively, it is known that in many situations, teams will produce better problem-solving and decision-making outcomes than individuals will do in working alone [7]. "The improved outcomes are partially due to team interaction gains that result from pooled individual information" [7].

Team decision-making is a subject that has been addressed by many authors in the scientific literature [8, 9, 10, 7]. From all the factors that are presumed to influence team decision-making, the selection of an appropriate combination of members is a key one. "The leader should have a style that fits the project, individuals should have the necessary complementary task work skills and teamwork skills, and the team should not be so large that communication becomes difficult" [11]. One aspect that must be considered as key to the quality of the Estimate Process result is the expertise of the individuals that are part of the planning staff. Accordingly, the team should be selected according to each operation to be planned.

The composition of the team can be challenged. Critiques could be provided based on the strengths and weaknesses of a proposed team according to the experience and training needed for the planning of a specific operation as well as on their teamwork skills. Ideally, the team members' expertise areas of the planning staff should cover the expertise needed for the planning of each operation based on the knowledge of the area of operations, the enemy's forces, cultures, politics, etc.

Furthermore, the assignation of the tasks to the different team members can also be challenged. Do we ask the right thing to the right person? Critiques could be provided based on the strengths and weaknesses of having an individual executing a task according to his expertise, aptitude, etc.

2.2 The decision-making strategy

The parameters of the dynamic of the team are set in this stage. The chief of staff (COS) is the key player to select the decision-making strategy. The decision-making strategy is the process used by the team to reach any decision (such as the factors to consider, the COAs, and the selection of the most appropriate one) during the Estimate Process.

Methods of decision-making can be seen on a continuum with one person having full authority on one end to everyone sharing power and responsibility on the other [12]. The basic ways that team make decisions are [13]:

- Command Decision: An individual on the team can make the decision based on his/her own information;
- Consultative Decision: An individual on the team can make the decision based on input from other team members;
- Majority: The team can vote and base the decision on the majority;
- Consensus Decision: The whole team can work to decide on an option that everyone can support;
- Unanimous agreement: The team can have everyone agree on one option.

The decision-making strategies usually used in the Estimate Process are the vote or the consensus. No matter the strategy selected, it is important that the team understands the process and is comfortable to execute it. This involves that each team member must understand (master) the strategy used. The vote, which is a quite well understood decision-making strategy, seems to be very easy to use. Consensus seems to be more difficult to execute. This may be due, in part, to a partial understanding of the consensus process to be executed. Effectively, even if many formal consensus processes have been proposed in the literature [12, 14, 15, 16], no formal consensus process is used during the execution of the Estimate Process. For example, all formal consensus processes proposed in the literature require a commitment to active cooperation, disciplined speaking and listening, and respect for the contributions of every member [12]. Generally, the team is taking possession of all proposals/ideas (the proposal is not the property of the presenter anymore). During a discussion, each proposal is challenged by raising any concerns the team members may have. Then, everyone in the team works to improve the proposal to make it the best decision for the group.

Accordingly, the execution of the decision-making strategy can be challenged. Critiques could be provided based on identifying the strengths and weaknesses of the execution of the decision-making process selected. For example, in a consensus process, it could mean to notify that some identified concerns have not been solved or that some proposals have not been studied, etc.

2.3 The planning tools

The initiation stage is the phase to set the physical environment that will be used for executing the planning. Paper maps with coloured stickers, binders of papers, whiteboards, flip charts and computers with different software and Internet are usually the tools used by the planning teams. As part of the planning tools to be identified and

gathered, there are the different sources of information and knowledge that can be needed to achieve the planning. These sources of information/knowledge may be automated (such as lessons learned database and resource database) or not (such as best practices, doctrine and specific areas of expertise).

It is very important that the team has access to all appropriate and available sources of information, and is aware of the level of accuracy of these sources. Accordingly, the sources of information used can be challenged. Critiques can focuses on the availability of any sources of knowledge needed as well as on the credibility of the information of these sources. Focussing on the credibility of the knowledge, Sylverman [17] has identified four tests (clarity, coherence, workability, correspondence) that indicate if observers will reject a body of knowledge. Those could be used to provide critiques of a knowledge base or a database.

Furthermore, since that more than one knowledge base may be consulted, conflicted knowledge may exist. Critiques can also be produced based on detection of conflicted as well as concordant evidences among different sources of knowledge.

3 Orientation Stage

In the *Orientation* stage, the "Commander must orient the staff towards the requirements of the new operation" [1]. To orient the planning, a mission analysis will be conducted. It is an exercise between the commander and key staff to designate the centre of gravity, the end state and criteria for success for the staff. This is a key activity in the CFOPP, which has two objectives: determine the nature of the problem and confirm the results to be achieved. This work is based on a review of the situation as well as a review of the higher command level intents. The output of the orientation stage is the commander's planning guidance.

At this point, one can question these aspects:

- The analysis of the situation;
- The mission statement.

3.1 The analysis of the situation

In order to determine with precision what the mission will be, the planning staff will go through an analysis of the situation called the mission analysis. To do so, they need to understand the higher commander level intent and identify all factors that can constitute an issue to the operation (these are called planning staff factors).

The list of factors that is identified may be challenged. Effectively, critiques could be related to the accuracy and the exhaustiveness of this list.

3.2 The mission statement

The mission statement that is defined at this stage describes:

a. Who (what types of forces) will execute the action?

b. What type of action (for example attack, defend) is contemplated?

c. When will the action begin?

d. Where will the action occur (area of operations and objectives)? And

e. Why (for what purpose) will each force conduct its part of the operation?

Accordingly, the description of the mission statement may be challenged. Each one of its elements can be critiqued based on the clarity of its formulation.

4 Course of Action Development Stage

A COA is composed of a sequence of phases, and is represented by sketches. In brief, the COAs should answer the fundamental questions of:

- a. When: When does the action begin or when must it be completed?
- b. Who: Who will conduct the operation?
- c. What: What military operations are being considered?
- d. Where: Where will they be performed?
- e. Why: Why are the operations being conducted?
- f. How: How will the operations be conducted?

The *Course of Action (COA) Development* stage starts with a review of commander's guidance to ensure that all staff develops a common understanding of the commander's intent, and that this understanding is consistent with the intent of the commander. Then a staff analysis is executed to identify the factors and the derived deductions that are relevant to the operation being planned as well as to determine whether the mission is achievable based on limitations imposed by higher authorities. Following this step, realistic enemy COAs are developed and effects associated with them are analysed. Own forces COAs are also developed and analysed to determine 1) their viability; 2) how they counter the expected enemy COAs and; 3) how they respect the principles of war or tenets of joint warfare. Own COAs are then validated with the commander and adjusted according to his comments/preoccupations. Validated COAs are compared among them and the result of the comparison is presented to the commander, so he can select the COA that is the most appropriate to the situation according to his point of view. The output of the COA development stage, which is also the output of the Estimate Process, is the CONOPS.

The output of the COA development stage, the CONOPS, is also the output of the Estimate Process.

At this point, one can question these aspects:

- The COA development process;

- The understanding of the goal to be achieved;
- The staff analysis;
- The enemy courses of action;
- The friendly courses of action;
- The comparison of the friendly courses of action.

4.1 COA development process

The intent of the COA development process is that some functions need to be addressed in a certain sequence; for example, the COA should not be developed before the situation is understood. To do so, the pertinent factors must have been identified and understood, and the team must focus on the critical factors to the mission, avoiding spending too much time on details that are not so important. Then, an acceptable set of options should be defined before the decision is made [6]. If new information is received or an hypothesis modified, the team can always go back in the process to review/modify previous deductions, COAs.

This sequence of functions can correspond to the behaviour of experience planners: "Instead of dropping pattern recognition in novel situations, experienced decision makers learn to pause and think critically about the results of recognition." [18]. It is interesting to notice that, experienced Army planners do not necessary spend less time planning than novice planners [19]. Effectively, "experienced planners did not generate an initial plan more rapidly (e.g., based on similarities with prior situations), tended to see the situation as more complex, and felt the need for more time to think about their plan than novices"[18].

By simplifying the COA Development as a set of steps (Figure 2), we can imagine critiques related to the detection of any omission of any of these steps. Such critiques could focus on the possible impact of these omissions.

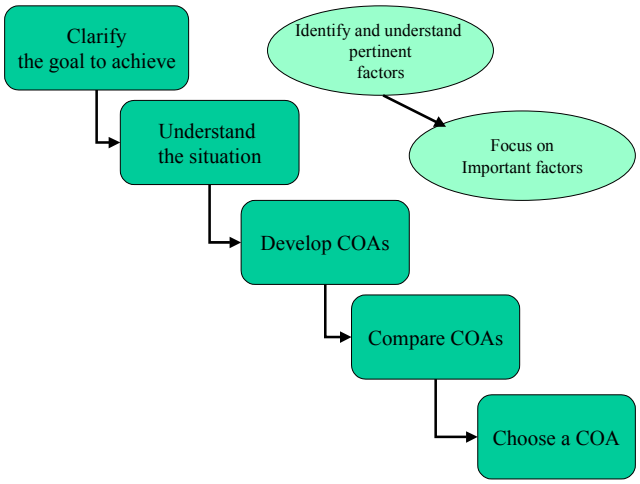

Figure 2. COA development view

4.2 Understanding of the goal to be achieved

The planning staff needs to develop a common understanding of the Commander's guidance through exchanges among the team members. This common understanding can be seen as a common/shared mental model that need to be developed. This common mental model is composed of a subset of each team member's mental model.

Previous work on team decision making have identified the importance of a shared mental model. For example, Cohen mentioned: "Team decision making depends on shared mental models of the task, the situation, and the communicative processes within the team that create and maintain such shared knowledge" [7].

Based on his work on critical thinking, Cohen [18] identified three types of problems in mental models: gaps, conflict and unreliable assumptions. Freeman [20] mentioned that critiquing "ferrets out specific sources of uncertainty, such as gaps in knowledge, untested assumptions, and the existence of conflicting interpretations of events". Then critiquing could lead to the detection of conflicts or gaps between the commander's intent and the team's understanding of the commander's intent or between the individual understandings of the commander's intent and the team's understanding. Furthermore, unreliable assumptions in the team's understanding of commander's intent could also be detected.

Accordingly, the team members' understanding of the goal (or their associated mental models) may be challenged based on detection of any difference between individual mental models with the team's mental model. Such detection may lead to the update of one human's mental model or the update of the shared mental model.

4.3 Staff analysis

A staff analysis is executed to identify the factors and the derived deductions that are relevant to the operation being planned as well as to determine whether the mission is achievable based on limitations imposed by higher authorities. For each one of these factors, the team has to identify the elements and their possible impact on the operation.

Accordingly the assessment (the gist of their impact) of each one of the factors can be critiqued. The critiques could be based on detection of errors in the assessments of these factors according to the doctrine, expert knowledge, lessons learned, etc.

Furthermore, the planning staff needs to develop a common understanding of the situation through exchanges among the team members. This common understanding can be seen as a common/shared mental model that need to be developed. This common mental model will be composed of a subset of each team member's mental model.

Based on the work of Cohen [18], it is possible to think about challenging mental model of each individual based on the detection of inconsistencies between individual mental models and team mental model.

4.4 Enemy COA

All enemy COAs (ECOAs) should be developed and analysed according to factors such as:

- Enemy's objectives in the area of operations;
- Enemy's capabilities;
- Enemy Centre of Gravity;
- Enemy's method of operations (doctrine and experience);
- Etc.

This analysis will lead to the identification of the most likely ECOA and the most dangerous one.

Accordingly, the exhaustiveness of the list of relevant enemy COAs could be challenged, as well as the assessment of their level of dangerousness and of probability.

4.5 Friendly COA

A COA is composed of a set of phases that will ultimately allow reaching the commander's goal. A COA can then be seen as a user's solution composed of a complex structure of tasks. Any conception problem within the plan itself must be detected. Such problems will be related to ambiguity (clarity), conflict (temporal or logical), incoherence (temporal or logical incompleteness and inconsistency) or reality mismatch in the structure of tasks within each phase of a COA as well as in the amalgamation of the different phases when considering them as a whole COA.

Furthermore, each COA is analysed according to:

1) Its viability: by considering the following aspects:
   - Suitability: does it achieve the mission, satisfy the commander's intent and accomplish the tasks? Does it counter enemy COAs?;
   - Feasibility: do force structure and resources exist to mount and sustain?;
   - Acceptability: does it account for limitations placed on the operation, is it worth the risk?;
   - Compliance: does it conform to approved CF doctrine and applicable policy, regulations, legislation and/or guidelines?
2) How it counter the expected ECOAs and;
3) How it respect the principles of war or tenets of joint warfare.

A COA also has to be considered on the basis of how it deals with the different issues (factors) that have been identified during the staff analysis. Another aspect that needs to

be considered is the different effects, direct as well as indirect (physical or psychological) caused by the execution of this COA. This notion of direct and indirect effects is at the core of the notion of effects based operations [21].

Finally, the team must make sure that this set of developed COAs covers well the different possibilities, that there is a good diversity of options among the different COAs.

Accordingly, a COA can be challenged based on:

- Detection of conception problem;
- An analysis of the staff analysis factors;
- Its viability;
- An analysis of enemy COAs;
- An analysis of direct and indirect effects;
- An analysis of the exhaustiveness of the list of COAs.

Furthermore, the planning staff needs to develop a common understanding of the assessment of each COA, through exchanges among the team members. This common understanding can be seen as a common/shared mental model that need to be developed. This common mental model will be composed of a subset of each team member's mental model.

Here again, it is possible to think about challenging the mental model of each individual based on detection of inconsistencies between individual mental models and team mental model.

4.6 The comparison of the COAs

Finally, when comparing many COAs, different factors/criteria can be considered. The team determines the ones that are going to be used, and the commander may give direction on specific factors that he may want to add. Then, the team members will have to determine which aspects are more important to consider than others. The assignation of priority to the different criteria may be challenges according to what has been seen in the past. Then, the COAs will be compared.

Accordingly, the criteria selected, the priority assigned to each criteria as well as the result of the comparison on each one of these criteria can be challenged.

5 Critiquing Systems for the Estimate

In the previous section, elements to be questioned in the Estimate Process have been identified. By challenging these elements, it is anticipated that the result of the Estimate Process could be improved. For each one of these elements, specific aspects to be looked at have also been identified. These aspects are:

- For the planning staff:

    - its composition;
    - the assignment of the tasks to each team's member;
  - For the decision-making strategy: the way it is executed;
  - For the tools used:
    - the availability of any sources of information needed;
    - the credibility of the sources of information;
    - the existence of conflicted as well as concordant evidences among sources of information;
  - For the analysis of the situation: the exhaustiveness of the factors identified;
  - For the mission statement: the clarity of its formulation;
  - For the COA development process: the detection of any step omission;
  - For the team's understanding of the goal to achieve: the detection of gaps in knowledge, conflicting interpretations of events and unreliable assumptions between team members;
  - For the staff analysis:
    - detection of error in the factors assessment;
    - detection of inconsistencies between individual and team mental models of the situation;
  - For enemy COAs:
    - the exhaustiveness of relevant ECOAs;
    - the assessment of its level of dangerousness;
    - the assessment of its probability;
  - For friendly COAs:
    - the problems of conception;
    - the staff analysis factors;
    - the viability analysis;
    - the enemy COAs analysis;
    - the effects analysis;
    - the diversity of the COAs;
  - For the team's assessment of the COAs: the detection of gaps in knowledge, conflicting interpretations of events and unreliable assumptions of the assessment of the COAs;
  - For the comparison of COAs:
    - the criteria selected;
    - the priority assigned to the different criteria;
    - the assessment of the COAs according to the different criteria.

Considering that these aspects could be used to provide automated critiques is an interesting avenue for decisions support systems. This approach is different from traditional decision support systems that are mostly developed to assist a user in the

creation (conception) of one or many elements of a decision. A critique can be considered as a feedback on user's outputs. It puts the emphasis on making a user more conscious of all aspects of its propositions/statements/decisions.

Automated critiques can be produced by computer-based critiquing systems (also called critiquing systems). Such systems observe the inputs and decisions of the user and try to verify the decisions while drawing attention only in critical situations [22]. Vahidov and Elrod mentioned that the primary purpose of critiquing systems is to monitor the user's actions and indicate possible errors [23]. Then, the core task of critics is to recognize and communicate debatable issues concerning a product [24]. Critics point out problematic situations that might otherwise remain unnoticed. Accordingly, a critiquing system is a tool that allows the decision-maker to be "fully" aware of the advantages and disadvantages of a solution. It can also provide some kind of guidance on how to improve the proposed solution [23]. In brief, critiquing systems do for experts what intelligent tutoring systems do for novices [17].

Since critiquing systems help users in designing solutions themselves, as opposed to having a traditional expert system design solutions for them, it provides a more cooperative approach to problem solving [24]. Furthermore, it is expected that some of the benefits of the cognitive activity of critiquing will be effective for computer-based critiquing systems. These include the growth of knowledge, error elimination and the promotion of mutual understanding by all participants [24].

Since critiquing systems are also known to be well suited for situations where [24]:

- Knowledge is incomplete and evolving;
- The problem requirements can be specified only partially; and
- Necessary knowledge is distributed among many participants;

their use for the Estimate Process seems to be very adequate. However, to be practically useful, critiquing systems must have these proprieties [22]:

- Critiquing systems should not ask for additional information too often, otherwise the system disturbs the user more than it helps;
- Critiquing systems should be able to help the user in situations where only partial information is available;
- Critiquing systems should be able to focus on critical situations.

Also, to be efficient, these systems must be adapted to the process to be executed as well as to the team that has to execute the process.

Three categories of critiquing systems can address the different aspects identified in the previous section. There are the ones critiquing:

- The different products that are produced during the Estimate Process:
  - The list of the people composing the planning staff;
  - The list of planning tools;
  - The situation analysis;
  - The mission statement;

    - The staff analysis;
    - The enemy courses of action;
    - The friendly courses of action;
    - The comparison of friendly courses of action;
- The different processes to be executed in order to go through the Estimate Process:
    - the decision-making strategy;
    - the COA development process;
- The team's mental models:
    - the team's understanding of the goal to achieve;
    - the team's understanding of the situation;
    - the team's assessment of the COAs.

Now, we needed to determine which ones of them could be designated as cognitive support tools. Basically, our approach consisted to designate as cognitive support tools only those that directly counteract at least one of the biases presented in the Wickens and al.'s study.

5.1 Critiquing systems for the different products

Based on the aspects that have been identified to provide critiques about the Estimate Process outputs, different critiquing systems could be developed to identify their strengths and weaknesses. These critiquing systems would need to be able to have a representation of the different elements of the Estimate Process (the situation, the COAs, the decision-maker's preferences). Furthermore, they would need to have access to domain knowledge (such as best practices, lessons learned, doctrine and expertise) as well as being able to build and maintain dynamic individual as well as common user's models [25].

Existing systems have already been developed to critique COAs. For example, Disciple-COA provides strengths and weaknesses of a military COA. Disciple-COA agent critiquer examines a military COA, outlines its viability and correctness, and demonstrates its strengths and weaknesses with respect to the U.S. prescribed principles of war and tenets of army operations [26]. INSPECT has addressed the COA critiques concerned with plan structure and resources. It can check the hierarchical structure of an air campaign plan, identifies incomplete or incoherent objectives, and performs rough feasibility estimation based on available resources [27,28]. LOOM-based COA critiquer has worked on providing critiques of COA decisive points [29]. Protégé-based COA critiquer has addressed the soundness and feasibility of a COA to highlight doctrinal problems in a human-generated COA [30]. Military shaken critiquer has been developed to provide critiques based on different dimensions of the battle space such as Risks, Casualties, Maneuver, Effectiveness, Command and Control, Terrain Use, Preparedness for Enemy Response, Simplicity, Resource Use, and Synchronization [31].

It is important to notice that all these critiquing systems have been developed principally to test knowledge bases. Indeed, we have found very few information on their integration into a military decision-making process.

From our work, we consider that the systems critiquing:

- The situation analysis;
- The staff analysis;
- The enemy courses of action;
- The friendly courses of action;
- The comparison of friendly courses of action;

can be considered as cognitive support tools. In fact, the kind of critiques that have been described for these systems directly counteract biases associated with receiving and using cues as well as biases associated with hypothesis generation, evaluation and selection. Even if the other critiquing systems would be useful as support systems, they can not be designated as cognitive support tools since their critiques would not directly counteract any Wickens and al.' bias.

5.2 Critiquing systems for the different processes

By identifying the different steps of the process to execute, we can imagine a critiquing system capable of detecting omission of any of these steps and advise the team of the possible impact of this fact. Such critiquing system will need that the team use a computer-based infrastructure to exchange information. Automated workflow systems could be used as a basis for such critiquing systems.

Since detection of step omissions would not directly counteract any described biases, these critiquing systems are not designated as cognitive support tools.

5.3 Critiquing systems for monitoring the mental models

In order to monitor mental models, a critiquing system should monitor the exchange of information (the discussions) between the team members, used them to build a representation of the mental model of each individual in order to detect any conflicts or gaps between the commander's intent and the team's understanding of the commander's intent or between the individual understandings of the commander's intent and the team's understanding. Furthermore, it could detect unreliable assumptions in the team's understanding of commander's intent. Such critiquing system will have to be able to define and keep in record a profile of each team members (user's models), including the commander's profile, as well as a profile for the team. Furthermore, they will need that the team use a computer-based infrastructure to exchange information.

The same concepts stand for the monitoring of the team's mental models of the situation as well as the COA assessment.

Since detection of conflicts, gaps or unreliable assumptions would not directly counteract any described biases, these critiquing systems are not designated as cognitive support tools.

6 Conclusion

The CFOPP can be seen as a coordinated process for preparing plans and orders for CF operations. The Estimate Process, which consists of the three first stages of the CFOPP, involves the elaboration of different COAs following situation analysis and the selection of the most appropriate one for its subsequent planning.

The Estimate Process is often performed under time pressure and stressful conditions related to the fact that military operations are evolving into a dynamic, complex and uncertain environment. Under the influence of these factors, the human capacity of reasoning and judgment can be significantly reduced. Since time pressure and stress may negatively affect the human judgment and capacity of reasoning, it can be said that factors such as the time pressure and stress may negatively affect the commander and team's assessment of the situation as well as the assessment of the COAs. Then, the use of computer-based decision-aid systems supporting the commander and his team appear to be an interesting avenue for the improvement of the Estimate Process.

The goal, the understanding of the situation, the courses of action, the decision-maker's preferences, and the course of action selected can be considered as the elements of a military decision. Most of the decision support systems developed so far intend to assist a user in the creation (conception) of one or many of these elements. A different approach would be to provide user's outputs feedback. The type of feedback that we are studying is the possibility to challenge/critique user decisions. Such approach is directly in line with the concepts of critical thinking.

In this document, different elements to be challenged are presented for each stage of the Estimate Process. Even if we think that this study represents a good overview of the different types of elements that could be challenged, we do not pretend that this list is exhaustive. Based on these elements and the associated aspects to consider, computer-based critiquing systems (also called critiquing systems) have been identified. Critiquing systems are not like other types of advisory systems on different aspects:

- Type of input: The solution of the user is provided as an input to a critiquing system, while it is not the case to other types of systems;
- Type of output: A critiquing system provides a list of strengths and weaknesses of the user's solution instead of providing a solution;
- Type of interaction: A critiquing system determines the right information to be provided at the right time, while other systems will respond in real time to a user request or to a predetermined moment in a sequence. The level of autonomy of such a system is usually higher than other types of advisory systems since it tries to make the user aware of the critical issues and their impact when they are raised. Furthermore, justification and explanation

facilities are common in such a system, even argumentation facility is expected.

Then, from that list of critiquing systems for the Estimate Process, three categories of critiquing systems have been identified. First, there are those critiquing results such as the mission statement, the evaluation of the situation, the COAs, the assessment of the COAs, the comparison with the COAs, the composition of the team, the different sources of knowledge. Second, there are those critiquing a process executed by the team members to accomplish the planning. Third, there are those critiquing the perceived mental models of the different team members to make sure that the team has a common understanding of the subjects discussed.

Since our intent was to demonstrate that critiquing systems could be considered as cognitive support tools for the Estimate Process, we have identified those that could directly counteract at least one bias that affect cognitive processes. Based on our work, the critiquing systems that could be considered as cognitive support tools are the ones critiquing:

- The situation analysis;
- The staff analysis;
- The enemy courses of action;
- The friendly courses of action;
- The comparison of friendly courses of action;

It can be argued that some of the other ones could also provide a cognitive support to the Estimate Process. But since these ones needed a further analysis on how they could counteract biases, it was decided to limit our study to the obvious ones. Furthermore, many other aspects need to be addressed. For example:

- What types of critique would be more efficient for the Estimate Process?
- By providing a list of weaknesses, would a critiquing system be perceived by the users as too negative?
- Will the user trust the result of a critiquing system?
- Will the user trust too much such a system?
- Will the integration of a critiquing system into a team dynamic be disruptive?

Finally, we consider that the approach we used to identify cognitive support tools for the Estimate Process is of high interest for other decision-support systems. By knowing the different critiquing systems that would be worthwhile to be developed and the kind of biases that these systems could counteract, designers are in a better position to propose systems that will fit the holistic concept of decision support considering process requirements as well as human factor requirements.

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