COMPUTER-AIDED DECISION SUPPORT: IS IT WHAT THE ARMY NEEDS?

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There has been a call for computer-aided decision support in Army and other military operations as a result of the increasing pace of current and future warfare. These tools are expected to speed up the critical thinking process, for example in battle planning and course of action analysis, by providing users with critical information and off-loading various cognitive tasks. There is a need, however, to determine the kinds of decision tools that are best suited to Army operational needs and to consider the potential implementation issues associated with application of automated tools to complex operations. A structured approach is needed to analyze Army operations and reveal the critical information needs associated with the various positions, and to determine what is appropriate in terms of decision aiding systems. Understanding information needs and adequately designing for human integration with decision tools will be important to successful overall system performance.

INTRODUCTION

A military battle can be decided by a command staff's ability to make good decision quickly. The complexity and fast pace of modern and future combat situations has increased the perceived need for computer-based decision tools in the command post. Battle commanders and staffs must integrate large amounts of data from many sources, including various sensors, media devices, and other staff members, to make decisions. For example, the brigade operations officer (the S3) must actively participate in the development of plans and feasible courses of action based on the terrain and weather, current and future areas of operation and boundaries, projected enemy actions and locations, friendly combat status and readiness level, mission type, available resources, and other battlefield information. This data often varies over time and space, but must still be accurately perceived and comprehended in order to acquire high levels of awareness regarding evolving battlefield events (Shattuck et al., 2000). Furthermore, the battle staff is often working under stressful conditions where distractors can prevent them from integrating newly acquired information with what is already known or impede their ability to recall solutions from previous battles or training exercises. Thus, there has been a call for intelligent aiding systems in the military command post to aid in information processing and situation assessment (Kewley, 1997; Ntuen et al., 1998; Bowman et al., 2001).

DESCRIBING DECISION AIDS

The research focus for decision aids has been on providing intelligent agents for development, evaluation, and selection of battlefield courses of action (COAs). COAs are possible plans for the commanding officer (CO) and staff that they may use to accomplish the stated mission of higher headquarters. For example, Bowman et al. (2001) suggest that computerized agents — oblivious to time, fatigue, and environmental stressors and programmed with lessons learned and doctrinal knowledge — should be developed and implemented to evaluate COAs and list strengths and weaknesses of each for the CO. This would allow the staff to scan the information, discard unwanted options, critically evaluate the solutions, and select the most appropriate action.

A plethora of terms has been used in recent literature to describe these kinds of tools – automated decision aids, intelligent agents, computer assisted analysis or problem solving expert systems. Each has been defined using slightly different characteristics. For example, Maes (1994) defines automated decision aids as systems that provide a complimentary style of interaction and allow for cooperative processing in which both the user and system are capable of initiating communications, monitoring events, and performing tasks. Fischer and Reeves (1991) define cooperative problem-solving systems as computer-based tools that augment a person's ability to create, reflect, design, reason, and decide. Generally, though, researchers discuss decision aids as potentially affording similar benefits to the human user, by aiding in processing vast quantities of data and through their ability to reduce human error and improve human judgment. These systems are thought to guide humans through their decision making processes in both structured and unstructured environments.

IMPLEMENTATION ISSUES

There are numerous potential drawbacks to the application of automated decision aids. Though introduced with the explicit goal of reducing human error in decision making, they may paradoxically change the way humans make their decisions, alter where they allocate attentional resources, and change the kinds of errors that they make. One implementation issue involves determining the appropriate presentation of information to the user. That is, how much data, and in what form, should be provided to the user? Additionally, how and when should this data be updated such that users can adequately access and integrate it with their own conclusions? Systems that automatically update or change the content on visual displays (e.g., digital maps used in military operations that include information on friendly and enemy units) often result in users watching the display without taking-in or integrating what is presented with what they already know about the situation (Henderson, 1999). Similar results may be observed with automated information filtering and data fusion. Increased automation in data processing may lead to degradation of situation awareness (SA), which is a critical factor in highly complex and dynamic environments, like military operations. Filtering, fusion, and sophisticated presentation techniques may fail to provide users with the appropriate information or critical cues they need, thus denying the opportunity to build-up SA over time, compromising the ability to accurately project future states of the environment, and, ultimately, negatively affecting decision making.

The occurrence of decision biases is also a critical implementation issue. Operators may misuse decision aids by passively relying on their solutions, rather than actively participating in the decision process. This phenomenon discussed by Skitka et al. (1999) is described as the use of decision aids as a heuristic replacement for vigilant information seeking and processing. The problem has been observed in decision aids that have been prototyped for Army COA planning, analysis, and evaluation.

The Fox GA system was designed to assist operations and planning staff by rapidly generating a number of alternative COAs and providing a visualization environment for evaluating the merits of each COA, including scores of acceptability for each derived COA (Hayes and Brodie, 2001). The system is intended to speed up the development of COA options, to make the identification of feasible options easier, and increase the speed of comparison between options. In an evaluation of the system, Hayes and Brodie found that some subjects used the system like a video game, failing to consider the limitations of the decision support tool. These users were over reliant on the system-derived solutions. Some decision makers treated the evaluation scores for a given COA as truth, rather than suggestion, and were observed trying to tweak options until the score provided by Fox was as large as possible. This appeared to be done without consideration of whether they agreed with the system-derived solutions or an assessment of potential violations to doctrinal requirements.

The above example speaks to the need to determine the best way to facilitate effective human-automation symbiosis. A fairly wide body of research has shown that the overall performance of a human-machine system is contingent upon the effectiveness of the integration of the two agents, as well as on the capabilities of the individual agents. This integration is a function of not only the information displays and interaction format provided, but also of the fundamental design decisions regarding which functions the automated decision aid will take over or assist. For example, Endsley and Kaber (1999) found there were significant benefits for systems that took over or supported the human user in the implementation portion of a task, but lower overall performance when the human and the automation had to coordinate on activities like generation of decision options or joint selection of options.

To avoid the above implementation pitfalls, it may be necessary to determine the types of decision aids best suited for a given operation/domain. For example, what type of decision aid will work best for domains like credit management, where decisions are based on a few, and primarily quantifiable, factors like the number of missed payments, delinquent accounts, the duration of delinquency, and the number of active credit accounts? Versus, what is best for Army operations where decisions are based on data that is integrated from multiple sources, and on many factors, most of which are not quantifiable, including, terrain and weather conditions, enemy combat power, friendly combat readiness, and the availability of fire, air, and combat support? Furthermore, in battle situations there are often large gaps in the available information, errors in the data, and assumptions instead of facts. There are also often several potential solutions that could work in a given situation, rather than just one. Army decision makers, and thus any applicable decision aids, must take also into account appropriate strategies and tactics, as well as standard operating procedures and army doctrine. These issues make answering the question of what's best for the army complicated. In search of an answer, there should be consideration of the available classes of decision support and what they might do for the Army user.

CLASSIFYING DECISION AIDS

Steven Atler (see Power, 2001) developed a taxonomy of decision aids to classify the kinds of tools available, however, his descriptions fall strictly within a business framework. He identified file drawer systems, data analysis systems, analysis information systems, accounting and financial models, representational models, optimization models and suggestions models. The first three types were often referred to as data-oriented or data-driven; the second three types were called model-oriented or model-driven system; the suggestion type has been called intelligent or knowledge-driven. Power (2001) expanded this classification scheme, but maintained the business framework. They described 5 types of decision support tools: data driven DSS, model driven, knowledge driven DSS, document driven DSS, and communications driven or group DSS. These classes are useful for grouping business-related DSS, but a more generic classification is needed for applications across many operational settings.

The taxonomy of levels of automation developed by Endsley and Kaber (1999) may be a starting point. They developed a 10-level classification of levels of automation (LOAs) that has applicability to a wide range of tasks. The taxonomy is based in four generic functions that are intrinsic to many complex and dynamic domains (e.g., air traffic control, aircraft piloting, and teleoperation). The tasks are: 1) monitoring; 2) generating; 3) selecting; 4) implementing. The LOAs in the taxonomy were formulated by assigning these functions to the human or the computer, or a combination of the two. The LOAs range from manual control to full automation, with several intermediate levels. Following their method, a decision space for establishing classes of intelligent decision aids based on functionality may be identified.

Automated decision aids are most often discussed in terms of the roles that they may take in the information or decision making process, or what they do for the user. Decision support systems may hide task complexity, take over repetitive tasks, train users or other systems, facilitate human-human or human-machine collaboration, retrieve, filter and fuse data, generate, evaluate or select solutions, or provide displays to support data visualization. They offer numerous kinds of support, but a few basic roles are identified: 1) data processing; 2) problem analysis; 3) monitoring/managing; 4) prompting, 5) visualization .

Data processors gather information, filter information, fuse or transform data. **Problem solvers** consider rules or procedural knowledge for generating solutions, evaluating and comparing solutions, what-if analysis, and selecting solutions for implementation. **Monitors/managers** perceive system states, user states and actions, and critical events, as well as manage function allocation across the human and the computer. **Prompters** remind users of actions, past events or data lists, alert users to critical or future events, and prompt users for information or actions. **Visualization** systems provide visual display tools (e.g., virtual reality, sophisticated mapping tools) to present behavior or environmental occurrences for extraction of information, understanding of what is occurring in a large data pool, or tactically evaluating a situation. (It should be noted that we are not suggesting that these classes describe all available decision aiding tools, but describe those that have been of interest to Army in recent literature.)

In many cases either the human or the computer may perform these tasks individually, or as a team. Further, the design of the system will dictate the degree of involvement of the computer aid in the information and decision process. The level of autonomy of the decision aiding tool could range from none to maximal (full automated control), somewhat like the LOA taxonomy of Endsley and Kaber (1999). Further complexity is introduced as systems may take on single or multiple roles at varying degrees of autonomy. For example, there may be data processing components coupled with problem solving systems, or function allocation managers coupled with prompters, etc., all of which might include some visualization component.

ADDRESSING THE ARMY'S NEEDS

It is not clear right now what the Army actually "needs" in terms of DSS. A complication is the fact that consideration of the Army's needs really should be future focused. Which tasks exist, how they are completed, and who is responsible for the tasks may change dramatically with introduction of the Objective Force and Future Combat System (US Army White paper, Concepts of Objective Force). A useful starting point for identifying the kinds of tools needed for successful decision making in Army operations is the illumination of situation awareness (SA) requirements for particular jobs

Situation awareness requirements analysis

A key to the design of "good" decision aids is to know what information and environmental cues the human is searching for or using as the basis for decision making. The role that the operators' goals play in decision making are also important. Goals and plans often direct which aspects of the environment attentional resources are allocated to ("top-down decision making") (Casson, 1983). Design of automated decision aids should include work to highlight the aspects of a given situation that are important to each person's decision making, as well as the goals that may drive the process.

Cognitive task analysis (CTA) techniques are methods for determining the cognitive processes and skills required to meet task goals. The focus is to illuminate the elements of performance that underlie the generation of goals and making inferences regarding the task. A form of CTA, called goal-directed task analysis (GDTA) has been used to identify operators' SA requirements and basic task goals. SA requirements are defined as "those dynamic information needs associated with major goals or subgoals of the operator in performing his or her job (as opposed to more static knowledge such as rules, procedures, and general system knowledge)" (Endsley, 2001). In GDTA, illustrated in Table 1, the major goals of a particular job class or position are identified, along with subgoals necessary for meeting each of the goals. Associated with each subgoal, the major decisions that need to be made are then identified. The SA requirements needed for making these decisions and carrying out each subgoal are identified. These SA requirements focus not only on what data the individual needs, but also on how that information is integrated or combined to address each decision. The results are obtained through interviews and observation of subject matter experts.

Table 1. Goal-Directed Task Analysis Format

Goal
  Subgoal
    Decision
      Projection (Level 3 SA)
      Comprehension (Level 2 SA)
      Data (Level 1 SA)

We have begun to complete analysis of brigade level army positions, including the Intelligence Officer (S2), Operations Officer (S3), Logistics Officer (S4), and the Fire Support Officer (FSO). Preliminary results of GDTA provide insight into the kinds of tools that might provide SA requirements associated with these position, as well as aid in comprehension and projection.

Logistics Officer Example

As an example, we present concepts for the S4 position based on preliminary findings of the GDTA for this position. The S4 is primarily responsible for coordinating logistics integration of supply maintenance, transportation, and services for the command. He or she must develop the logistical plan to support tactical operations, equip the units and replace personnel and equipment, and recommend/select major supply routes and logistical supply areas. Results of the GDTA reveal that the overarching goal for the S4 position is to maintain unit readiness by keeping units 100% supplied. The major goals for this position include: 1) projecting or predicting future supply needs of all units; 2) adjusting the supply plan based on current battlefield states; and 3) coordinating the supply scheme by acquiring, allocating, moving, and protecting resources (see Table 2 for an excerpt from the S4 GDTA analysis). In making assessments of the types of DSS that might support this kind of job, we began by taking a look at some of the major decisions that must be made and the SA elements that support these decisions.

Table 2. Excerpt of GDTA for S4 Position

<u>Maintain Unit Readiness</u>

1.0 Project future supply needs of units

What items will be needed by each unit at which location over time?

- ❑ Projected usage of each item over time
  - o Units in task organization
    - ▪ Type
    - ▪ Size
    - ▪ Equipment
    - ▪ Operation unit is involved in
      - • Mission requirements
      - • Mission timing
      - • Mission tasks
    - ▪ Projected location of unit over time
    - ▪ Past item usage rate for unit and mission type
    - ▪ Location of projected supply points
      - • Terrain
      - • Distance to supply points
      - • Mobility requirements
        - o Type
        - o Fuel requirements
        - o Logistics supplied organically

What items are needed by what units over time? How many items are needed? A DSS tool that is programmed with base knowledge of the equipment and resources required for a specific unit type might be applied. The system could be programmed with up-to-date historical trend data on tailored item usage rates based on unit type, equipment and weapon types, operational conditions, terrain effects, etc. (rather than the gross trend information that is currently available). The trend data might be graphically presented via a visualization medium. This might improve upon the S4's ability to project needs of units, as the system could base needs on more factors than the human might be able to consider in a timely manner. For example, if the unit involved is an infantry unit, the system might automatically project supply needs for food, water, clothing, weaponry, ammunition, etc. based on the number of infantry soldiers and the activities (e.g., attack vs. defense) they will be involved in, and historical usage rate data on a particular infantry unit. The tool could also prompt users to remind them to order items, in an effort to avoid omissions. For example, if the S4 requests wire for a barrier/blocking operation, the system could remind him/her that pickets are also needed.

Do I need to adjust the supply plan? Do I need to recommend that a unit be reconstituted or refitted? A battlefield monitoring decision aid might provide S4 officers with an up-to-minute graphical assessment of the status of units, perhaps using the green-amber-red symbology and percent effectiveness information typically used in the military. The system might gather data from sensors and other networked computers and visually present status information (e.g. ammunition or fuel level, equipment damage, personnel/troop losses) on units. The tool might also prompt the user when a particular unit falls below the criterion for effectiveness or combat readiness. The DSS could display the cause of ineffectiveness (e.g., low fuel vs low ammunitions vs personnel or equipment damage) so that the S4 can assess the severity of the loss or the urgency of supply needs. It might also remind the S4 of the priority of units in the battle. For example, if a unit in the main effort of the fight suffers heavy losses in terms of equipment damage, then the urgency of their re-supply might be greater. This can aid with decisions regarding changes in the supply schedule and the need to refit or reconstitute a unit.

When do I request the items be sent out to units? A problem solving tool might help to determine when items need to be shipped. The S4 must consider three factors: 1) a "launch no later than time"- based on the time to get the item to the unit, the upload time for the items, and the download time for the items; 2) a "launch no earlier than time" – based on the storage capability of the unit to receive the items, the perishability of the items, the mobility requirements of the units to received the items, and the time the item will become available to the logistics team; and 3) the predicted ability to combine shipment based on the types of items to be transported, the urgency of need for items, and planned movement of the units to receive items. A computer aid could take each of these considerations into account to calculate a "window" or range of time during which a shipment should be shipped out to troops. It could also monitor when items have been shipped, where they are, and prompt the S4 if items will arrive late or not at all. This may aid decisions regarding re-order or acquiring resources from other sources.

What items are available to me for sending to units? A decision aid designed with a mobile agent component would be of benefit for answering this question. At present, the S4 is not aware of all items that might be available or where those items are located. They currently request items and wait for confirmation of whether or not they will be transported to a specified supply point. A mobile agent could move through other systems and networks to identify available items, number of items on hand, and where the items are located. The mobile agent could then return to the user and present him with options regarding whom to request certain items from and how many might be available for allocation to units.

How many transport vehicles, and what type, are needed? A simple problem solver could be applied that is capable of determining the number and type of transportation vehicles needed for a particular shipment, based on location of the units or supply points, accessibility of those points, how many items have to be sent, the types of items to be sent, and the kind of transport vehicles available.

For each of these decision aiding examples, data could be collected and stored by the system and presented via some visualization medium/decision display. For this example, a suite of tools that are linked, allowing the S4 to easily transition between several decisions displays, would benefit the S4 during rapidly paced wartime operations. For example, the S4 could check on the status of a particular shipment by viewing a decision display for the transportation information (e.g., vehicle type, route) and transition to the shipment data (e.g., launch and arrival time, content) for the same shipment.

The S4 position is just one example of how the GDTA can reveal the kinds of support Army decision makers need. Work on other positions, like the S3 and S2, show that projection (e.g., projected enemy actions, confidence in intelligence information, enemy threat, etc.) and comprehension (e.g., boundary areas, critical enemy targets, objective areas, etc.) support tools are also needed to aid in decision making. In addition, because many of these positions appear to have overlapping information and situation awareness needs (e.g., on terrain, location of the enemy and friendlies, etc.), there is a need for a shared visualization tool that allows the brigade "team" to have a common picture of what is occurring on the battlefield, for example, for combat planning or wargaming.

CONCLUSIONS

Decision support systems are becoming more common to complex, dynamically paced operations and the design issues associated with them should be critically considered. Technological advancements in the near future will increase the application of these tools, but also present a challenge to designers in terms of determining which tools are best suited for a given domain or operational task. For the Army, there are presently an overwhelming number of functions to be carried out in battle and decisions to be made in the military decision making process: interpreting data and information, predicting what the enemy will do, diagnosing the current battle situation, planning for the logistical needs of units, monitoring progress of the battle, communicating with other units, etc. Any of these functions might currently be supported with decision support tools and the list of tasks may increase significantly in the near future as the make-up of the Army forces is changed. A structured analysis of operator goals and SA elements is needed in order to ensure we are addressing Army needs or needs in other domains. Results of the GDTA can reveal the underlying information needs and SA requirements for making critical decisions. Understanding these requirements and adequately designing for human integration with decision tools, will be important to successful human performance with decision support systems, no matter the operational setting.

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